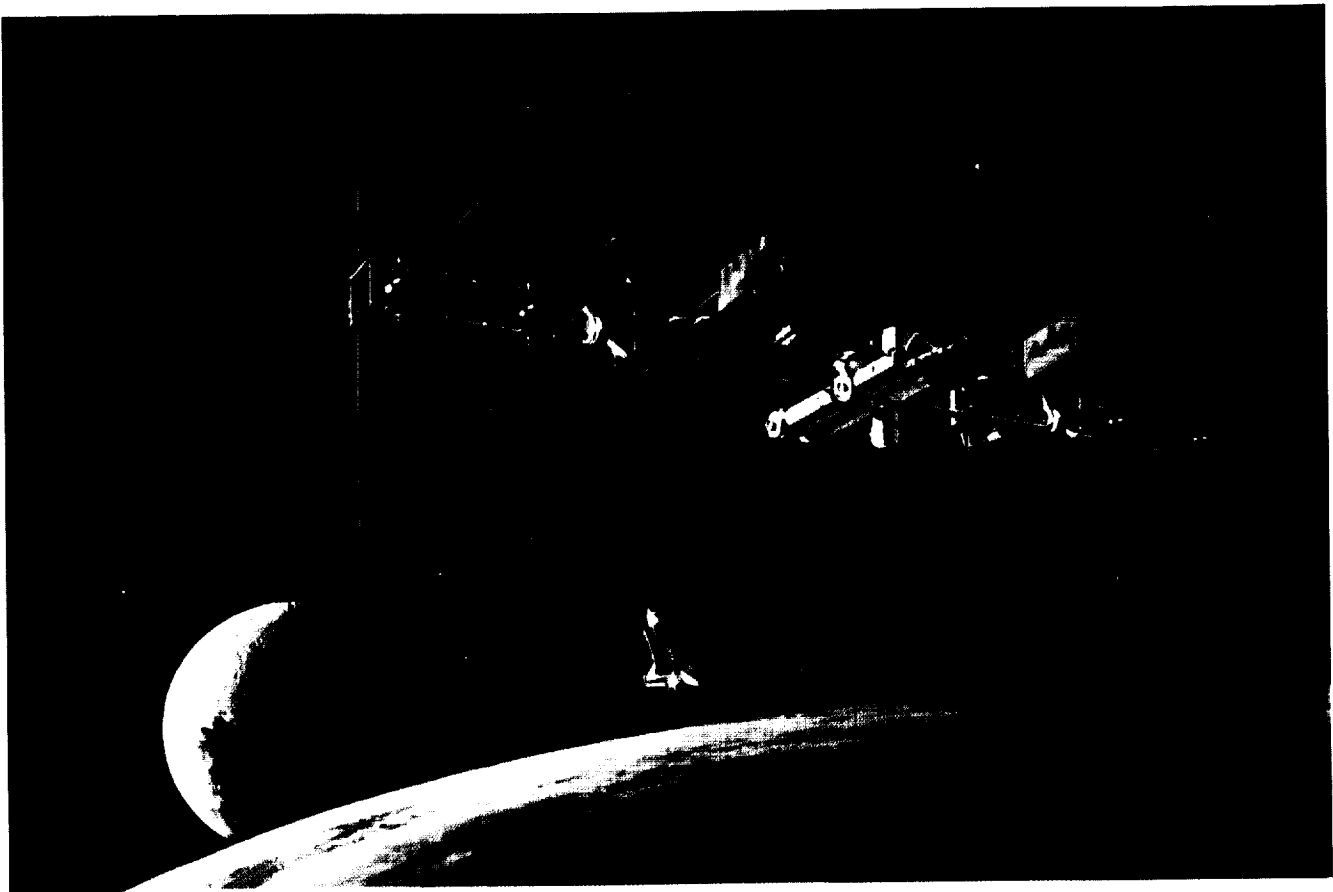


*Nashville, Tennessee  
3-5 November 1987*

# *Space Station* **WORKSHOP**



## ***Commercial Missions and User Requirements***

(NASA-TM-102912) SPACE STATION WORKSHOP:  
COMMERCIAL MISSIONS AND USER REQUIREMENTS  
(NASA) 326 p

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*Sponsored by*

# **NASA**





National Aeronautics and  
Space Administration

Washington, D.C.  
20546

Reply to Attn of:

February 23, 1988

Dear Attendee:

The National Aeronautics and Space Administration (NASA) is pleased to provide the proceedings from the Space Station Commercial Users Workshop held November 3-5, 1987, in Nashville, Tennessee. This Workshop was part of our initiative to provide U.S. industry with the opportunity to define its requirements for conducting commercial missions using the U.S. Space Station. NASA believes that it is important to continue the dialogue begun at the Nashville Workshop, and we are committed to meeting that objective.

During the 3-day Workshop, new ideas for commercial ventures were generated, important business and policy issues were raised, and many other recommendations were made. As you will see in the report, over 90 such items were recorded. We are in the process of preparing detailed responses addressing each of these issues and recommendations and will publish a report. During the next Commercial Users Workshop, we will discuss the status of these issues and recommendations.


The challenge to NASA and industry now is to continue the good spirit, progress and momentum generated during this Workshop. We must build upon it throughout the coming year as the Space Station Program progresses. To this end, we are conducting a vigorous follow-up from the Workshop. Accordingly, if there are initiatives that you would like to pursue or issues that you need help in resolving, please do not hesitate to contact us.

The results documented in these proceedings reflect the energy and hard work that went into preparing and conducting the Workshop and we are extremely pleased with the results. It represents a first step in rekindling the interest in industrializing space and in reasserting American leadership in space.

We recognize the need for NASA and industry to work together to facilitate industrial involvement in the Space Station Program, and we are looking forward to your continued participation in the civil space program.



James T. Rose  
Assistant Administrator  
for Commercial Programs



Andrew J. Stofan  
Associate Administrator  
for Space Station

Enclosure







## PURPOSE

This report provides the results and summary of the NASA Space Station Commercial Users Workshop held in Nashville, Tennessee, November 3-5, 1987. This Workshop was the first in a planned series designed to ensure that commercial user mission requirements are incorporated in the Space Station design. This report contains:

- Synopses and presentation materials from the Workshop plenary sessions;
- Summaries of Space Discipline Panel and sub-panel working sessions;
- Space Discipline Panel final reports to the Workshop, and;
- Conclusions, recommendations, and actions resulting from the Workshop.

## SUMMARY AND RESULTS

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# **EXECUTIVE SUMMARY**





# SPACE STATION COMMERCIAL USERS WORKSHOP

## SUMMARY PROCEEDINGS

### EXECUTIVE SUMMARY

#### BACKGROUND.

1. During the 1990's, the United States will complete a permanently manned Space Station which will offer broad opportunities for conducting space related R&D in low earth orbit. U.S. companies are presently involved with commercial space opportunities that include telecommunications, earth and ocean observation, and materials processing. The National Aeronautics and Space Administration (NASA) is involved in managing the U.S. Space Station development and deployment, and in encouraging and facilitating the Commercial Uses of Space.
2. In 1984, President Reagan committed the Nation to the goal of developing a permanently manned space station, and to do so within a decade. Since receiving that direction, NASA has worked hard on Space Station planning. The Space Station program has completed a Systems Requirement Review in March 1986, where the baseline configuration was established. The Station design is evolving and the Preliminary Requirements Design Review is scheduled for March 1988. The Space Station will be versatile and capable of conducting a wide variety of functions. The Station's design will feature pressurized laboratories, accommodations for attached payloads, and free-flying unmanned platforms. It will be a national laboratory; a research center in space. This laboratory will stimulate new technologies and enhance industrial competitiveness. It will further commercial space enterprises, and add greatly to our storehouse of scientific knowledge.
3. NASA is planning for U.S. industry to be a major user of the Space Station. NASA, working together with industry, has derived 78 potential commercial missions for the Space Station but the commercial opportunities on the Space Station are limited only by the imagination. NASA actively encourages industry to step forward with their proposed commercial ventures and to identify required Space Station capabilities. To facilitate this process, NASA is sponsoring a series of workshops which will provide U.S. industry with the opportunity to define their requirements for conducting commercial missions using the Space Station.
4. NASA, through its Office of Commercial Programs, aggressively promotes the commercial uses of space. With the exception of telecommunications, U.S. industry interest in commercial opportunities in space has slowed down since the *Challenger* accident. One of NASA's major goals is to expand opportunities for U.S. private sector investment and involvement in civil space and space-related activities. This policy is fully supported and encouraged by all levels of the Administration and the Congress.



5. Commercial opportunities in space currently consist of activities onboard the Space Shuttle and activities onboard and related to the Space Station. With the return of the Shuttle to operation, NASA will resume flight opportunities available to commercial users. NASA is also working to ease the processes by which commercial users become involved in the space program.

6. NASA, through its outreach program is attempting to get industry interested and involved in the space program. NASA is targeting firms in the non-aerospace industry as well as the traditional aerospace firms with high potential of becoming commercially involved in the space program. Initial market research was conducted which identified over 1800 potential firms. The most promising of these firms were contacted and formed the base invitation list to the first Workshop. The first Space Station Commercial User Workshop was to act as a forum for the non-aerospace community to gain an understanding of the commercial missions currently being planned for the Space Station and to make the Space Station Program Office aware of industry's additional requirements and concerns to conduct commercial missions on the Space Station.

7. The Workshop targeted approximately 150-200 participants. The target audience was R&D managers and project engineers with the intent on focusing on technical aspects of commercial missions and user requirements. The actual attendance was 254 distributed as follows:

NASA personnel	65
Industry *	155
Academia	24
Other	10
	<u>254</u>
Press	20

\* 86 companies represented

## WORKSHOP STRUCTURE.

8. The three-day Workshop consisted of a day and a half of presentations designed to give the audience an overview and orientation to the Space Station program, technical attributes of space, commercial opportunities, and some future industrial technology needs that may or may not have potential space-based solutions. The remaining time was dedicated to technical discussions on commercial opportunities in: Materials Processing in Space, Earth and Ocean Observation, and Industrial Services.

9. In order for NASA to gain a better understanding of what U.S. companies require for commercial missions, Industry Working Groups (IWG) were formed prior to the Workshop. These working groups were to identify the technology needs, problems or issues currently facing and anticipating each industry. For the first Workshop, three IWGs were formed in the following areas:

- Extraction (Mining, Agriculture, Petroleum, Fishing, etc.)



- Fabrication (Manufacturing, Automotive, Aircraft, Chemical, Pharmaceutical, Electronics)
- Services (Communications, Transportation, Retail Robotics)

10. During the Workshop, each IWG was given the opportunity to present its perspective of the technology needs and issues facing its industry over the next 5-10 years. The goal was for experts in space technology and research along with the industry participants to evaluate these requirements and to attempt to match them with currently planned Space Station missions. If no mission currently exists, one could be proposed for further development and consideration. These new requirements could have an effect on the Space Station design requirements.

11. After the industry groups presented their technology issues, the Workshop broke into three smaller groups (Space Discipline Panels) to discuss the needs identified by the IWGs, discuss Space Station technical requirements, generate proposed commercial ventures, and to identify other issues that presented barriers to space commercialization. The three Panels consisted of space experts from NASA, academia, and industry experts in the appropriate disciplines. These panels were augmented with the additional participants at the Workshop. The three panels were further divided into 12 sub-panels to conduct the detailed discussions.

## WORKSHOP RESULTS.

12. The Workshop resulted in: suggested changes to existing missions, new mission requirements, research recommendations, proposed commercial ventures, identification and discussion of barriers to commercialization, and specific actions that NASA should take regarding commercialization opportunities. Approximately 100 separate items were generated and are being addressed by NASA and the Space Discipline Panels. The Workshop also resulted in some frank and useful dialog between NASA and the other participants. The discussions summarized and reported in this document are the consensus from the panels and sub-panels and are not solely the opinions of the panel and sub-panel chairmen.

13. **Materials Processing in Space.** The MPS sub-panels interest and discussions centered on scientific experiments that NASA and industry should pursue. The panel felt that in most areas the technology was not sufficient to support industrial commitment to commercial ventures. The MPS sub-panels recommended nearly 20 specific areas of research that NASA should sponsor and support. This research is required to prove concepts and feasibilities and stimulate industry interest in undertaking commercial efforts in space.

14. The MPS panel discussed numerous issues (technical, business, and policy) that presented barriers to commercial involvement in space. Chief among these issues were: the lack of flight availability and access to space; the treatment of proprietary rights; excessively long Joint Endeavor Agreement processing time; lack of tax incentives; and operational concerns (i.e. safety, the requirement for onboard analysis and systems).



15. The MPS sub-panels identified required Space Station facilities and industrial services. The facilities include powered free flyers, a high temperature furnace facility, integrated analytical systems, and fiber pulling equipment for glasses and ceramics work. The industrial service requirements include waste handling and sterilization, environmental health and safety, and water quality and quantity.

16. **Earth and Ocean Observation Panel.** The Earth and Ocean Observation sub-panel discussions dealt with actions required to realize commercial opportunities in various remote sensing applications. These sub-panels discussed in detail: the technical adequacy of current Mission Requirements Data Base (MRDB) remote sensing related missions, requirements for new missions to be included in the MRDB, the business and policy issues that need to be addressed, and recommended research opportunities that NASA should consider.

17. The sub-panels reviewed and commented on specific MRDB missions. The panels recommended for inclusion in the MRDB: ground probing radar, direct downlink, manned observations on the 28° platform, provision of analog data from the 28° and polar platforms, and pointable mounts for the Large Format Camera. The panel endorsed as having significant commercial value the following MRDB missions:

- COMM 1014, Remote Sensing Test, Development, Verification Facility onboard the core station (Advanced Applications and Non-renewable Resources);
- COMM 1015, Large Format Camera (Renewable Resources);
- COMM 1019, EOSAT Mission (Renewable and Non-renewable Resources);
- COMM 1020, Synthetic Aperture Radar (Renewable Resources);
- COMM 1023, Ocean Color Imager (Renewable and Non-renewable Resources);
- and
- SAAX 202, EOS on Polar Platform (Non-renewable Resources).

18. The panel discussed some key business and policy issues which require addressing: cost/pricing policies for NASA supplied services; priorities for TDRSS, power, and other platform resources; U.S. spatial resolution limitations on satellite imaging data; polar platform servicing schedules; and repeat coverage and timely data requirements.

19. **Industrial Services.** The Industrial Service sub-panel discussions emphasized that there were numerous commercial opportunities in the three Industrial Service areas: On-orbit Services, Transportation Services, and Ground Services. However, to realize these opportunities, there are several business, legal, policy, and institutional issues that must be addressed.

20. The On-Orbit Services sub-panel endorsed/identified potential commercial on-orbit services opportunities including: lab space, spacecraft servicing, attached payload management, co-orbiting facilities, polar platform facilities, facility support, and personnel support. The sub-panel also discussed important business and policy issues that need to be addressed: ownership definition, liability, specification, performance guarantee, regulatory issues, pricing policies, contractual issues, and international issues. The On-orbit Services sub-panel concluded:





- The private sector should approach NASA now with their concepts for providing commercial services for both the baseline and growth Space Station;
- NASA should develop mechanisms to effectively accommodate private sector initiatives; and
- Effective incorporation of commercial activity on the Space Station will significantly enhance and ensure the future growth of the civil space program.

21. The Transportation Services sub-panel recommended 13 specific actions to facilitate space commercialization, identified the primary barriers to commercializing space transportation, and proposed three new services/ventures. The recommendations ranged from procurement related issues that NASA should address to ways of increasing commercial involvement in the space program. The sub-panel identified the barriers to commercializing space transportation services as: the cumbersome government procurement process; resistance to institutional changes within NASA; and, insufficient articulation of NASA's strategic planning to industry. The sub-panel developed three proposed commercial ventures: a Heavy Lift Launch Vehicle payload delivery system, Expendable Launch Vehicle Logistics Carriers, and a Space Station Traffic Management System. The sub-panel concluded that to increase industrial participation in the Space Station:

- NASA must expand participation by the existing aerospace and related community; and
- Enhance assurances to space access.

22. The Ground Services sub-panel identified 13 specific potential commercial opportunities:

- Robotics applications for servicing Space Station
- Commercially provided TMIS access service
- Space Station operations by a commercial entity
- Hazardous materials processing at launch site
- Commercially provided communications from ground and Low Earth Orbit (LEO) via satellite
- Commercially provided communications to and from ground to LEO via ground stations
- Design and development of flight hardware
- Inventory of "space qualified" hardware components
- Integrated training
- Post flight receiving
- Flight support - development of ship platform launch facilities
- "Generic" robotics for Space Station experiment use
- Pre-launch payload processing and integration



## NEXT STEPS

23. The process of identifying new requirements and defining new missions is a continually evolving one. The requirements identified will be used by the Space Discipline Panels to follow up with the companies expressing interest in those missions and to define new missions that will be presented at subsequent workshops. The commercial missions identified in this and subsequent workshops will be used by the Space Station Program Office as input to the design of the Space Station.

24. NASA is addressing all the issues, recommendations, and actions generated at this Workshop. Many of the issues can be resolved within NASA, but others must be coordinated with other Government and international organizations. Other items will require study before final responses can be given. NASA will publish a status report on the responses to the results of this Workshop in the near future.

25. The United States is about to make a major investment to develop a permanently manned Space Station. If this national resource is going to have a positive impact on U.S. industry, then U.S. companies need to be involved in the design of the Space Station to ensure that the capability exists to address their needs. The Workshop was a successful first step in this process.



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# SECTION I

## INTRODUCTION



## INTRODUCTION

1. During the 1990's, the United States will complete a permanently manned Space Station which will offer broad opportunities for conducting space-related R&D in low earth orbit. In order to ensure that the capability to conduct a wide variety of missions is incorporated into the design of the Space Station, NASA is sponsoring a series of workshops which will provide U.S. industry with the opportunity to define their requirements for conducting commercial missions using the U.S. Space Station.

2. The first Space Station Commercial Users Workshop was conducted on November 3-5, 1987, in Nashville, Tennessee. This workshop was to act as a forum for the non-aerospace community to gain an understanding of the commercial missions currently being planned for the Space Station and to make the Space Station Program Office aware of industry's additional requirements to conduct commercial missions on the Space Station.

3. The three-day Workshop consisted of a day and a half of orientation and overview presentations on the Space Station program, the technical attributes of space, commercial opportunities in space, and industry technology requirements over the next 5-10 years. In order for NASA to gain a better understanding of what U.S. companies require for commercial missions, industry working groups were formed prior to the workshop. These working groups were to identify technology needs, problems or issues currently facing each industry, and those anticipated over the next decade. For the first workshop, three industry working groups were formed in the following areas:

- Extraction (Mining, Agriculture, Petroleum, Fishing, etc.)
- Fabrication (Manufacturing, Automotive, Aircraft, Chemical, Pharmaceutical, Electronics)
- Services (Communications, Transportation, Retail Robotics)

4. During the Workshop, each Industry Working Group (IWG) was given the opportunity to present its perspective of the technology needs and issues facing its industry. After the industry groups presented their technology issues, the Workshop broke into three smaller groups in an attempt to match proposed commercial missions with the identified needs to define new missions that address U.S. industry concerns, and to identify other issues that presented barriers to space commercialization. The final session summarized the results of the Workshop and proposed follow-up actions for NASA and the space discipline panels.

5. The process of identifying new requirements and defining new missions is a continually evolving one. The requirements identified during this workshop will be used by the space discipline panels to follow up with the companies expressing interest in those missions and to define new missions that will be presented at subsequent workshops. The commercial missions identified in this and subsequent workshops will be used by the Space Station Program Office as input to the design of the Space Station.



6. The Workshop was conducted on an invitation only basis. Participants for the Workshop were identified and invited based on their potential commercial missions on the Space Station. The Workshop target attendance was 150-200 participants. The actual total attendance was 254, distributed as follows:

NASA personnel	65
Industry *	155
Academia	24
Other	<u>10</u>
	254
Press	20

\* 86 companies represented

7. The United States is about to make a major investment to develop a permanently manned Space Station. If this national resource is going to have a positive impact of U.S. industry, then U.S. companies need to get involved in the design of the Space Station to ensure that the capability exists to address their needs. The Workshop was a successful first step in this process.

8. This report contains presentation materials and synopses from the Workshop plenary sessions (Section II), summaries of the Space Discipline Panel and sub-panel working sessions (Section III), and the final Space Discipline Panel Reports (Section IV). The conclusions, recommendations and actions resulting from the workshop are contained in Section V. The Appendix contains the Workshop attendance list, charts showing the process for industry involvement in the commercial space programs, and points of contacts.



**SECTION II**  
**WORKSHOP PLENARY**  
**SESSIONS**





## **SECTION II WORKSHOP PLENARY SESSIONS**

### **Orientation Presentations**

Introductory Remarks	Mr. Richard E. Halpern
Space Station Overview	Mr. Andrew J. Stofan
Office of Commerical Programs	Mr. James T. Rose
Industry Perspective	Mr. Edward Donley
Attributes of Space	Dr. E.A. Brown
International Activities	Dr. Hans E.W. Hoffmann
Space Station Technical Overview	Dr. John-David Bartoe
Space Station Utilization	Mr. Richard E. Halpern
3M Experience	Dr. Chris J. Podsiadly

### **Industry Working Group Presentations**

Extraction Industry Working Group  
Fabrication Industry Working Group  
Service Industry Working Group

### **Luncheon Presentations**

Astronaut Experience	Dr. Jeffrey A. Hoffman
A Congressional Perspective	Mr. Dave Clement

## INTRODUCTORY REMARKS

The NASA Space Station Commercial Users Workshop was opened with a presentation by Mr. Richard E. Halpern. Mr. Halpern welcomed the attendees to the Workshop and discussed NASA's expectations from the Workshop. He also discussed the concept of this Workshop, profiled the attendees, and discussed the Workshop agenda.

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# Space Station Commercial Users Workshop

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**3-5 November 1987  
Nashville, Tennessee**

**Richard E. Halpern  
Office of Space Station  
Director of Utilization and Operations**

## WHAT WE EXPECT TO ACHIEVE

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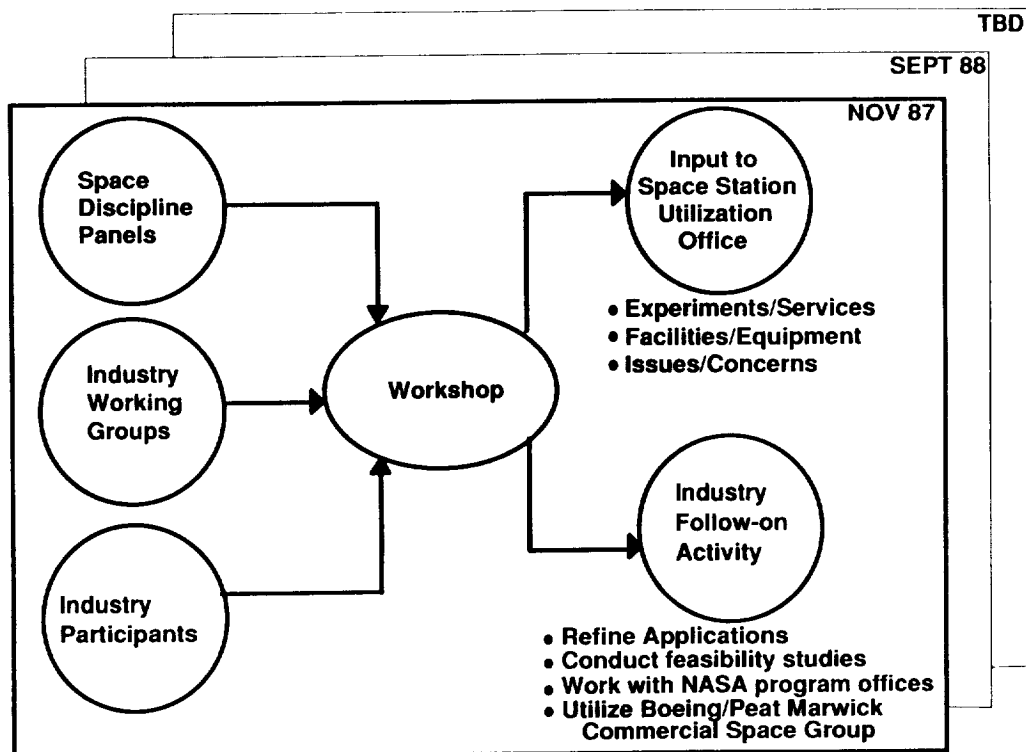
- Expose Industry to the research and service opportunities for the Space Station
- Gather Industry's inputs and requirements for the Space Station
- Understand Industry's issues and prerequisites for involvement in the program

We want your feedback

G NASA

## WORKSHOP CONCEPT

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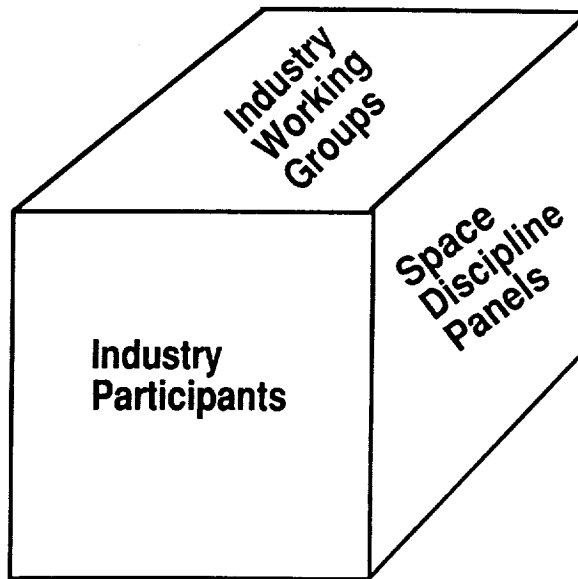


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## MULTI-DIMENSIONAL APPROACH

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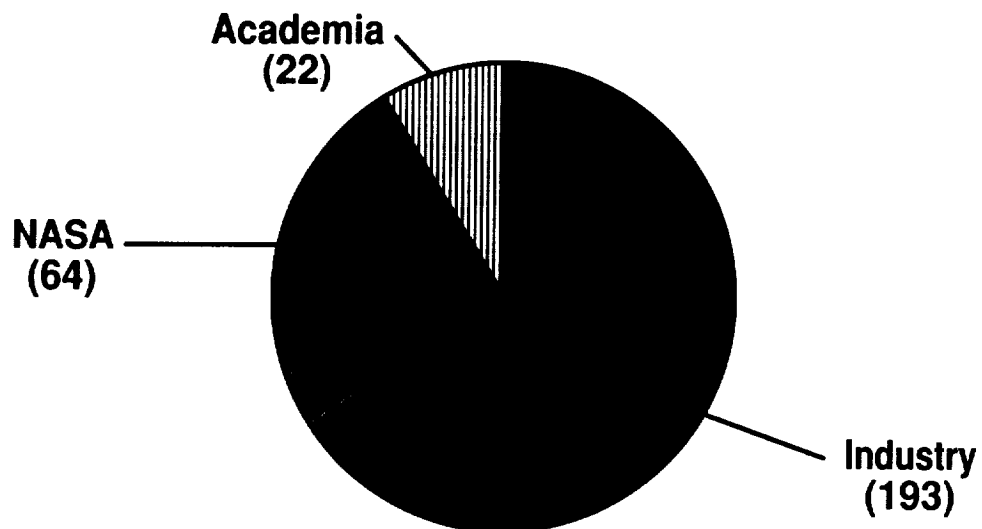
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## WORKSHOP COMPOSITION

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\* This group includes 141 companies

© NASA

# Space Station Commercial Users Workshop - Participants -

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<b>SPACE DISCIPLINE PANELS (Discipline Experts)</b>	<b>INDUSTRY WORKING GROUPS (Senior Executives)</b>	<b>INDUSTRY PARTICIPANTS (Industry Rep.)</b>
<b><u>Technology Areas:</u></b> <ul style="list-style-type: none"><li>- MPS</li><li>- Earth &amp; Ocean Observation</li><li>- Industry Services</li></ul> <b><u>Tasks:</u></b> <ul style="list-style-type: none"><li>- Present currently identified opportunities</li><li>- Identify &amp; describe available or planned equipment/facilities</li><li>- Mediate subpanel discussions to identify potential industry applications and issues</li><li>- Assess updates to MRDB</li></ul>	<b><u>Industry Segments:</u></b> <ul style="list-style-type: none"><li>- Fabrication</li><li>- Extraction</li><li>- Services</li></ul> <b><u>Tasks:</u></b> <ul style="list-style-type: none"><li>- Identify problems confronting industry sector</li><li>- Present issues at workshop</li><li>- Assign working level people as participants</li></ul>	<b><u>By invitation only:</u></b> <ul style="list-style-type: none"><li>- Interested Companies</li><li>- CCDS members</li></ul> <b><u>Tasks:</u></b> <ul style="list-style-type: none"><li>- Exposure to attributes of space, Space Station program, and commercial applications</li><li>- Identify potential industry applications</li><li>- Define new missions</li></ul>

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## AGENDA

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- Day One
  - Overview & Orientation
  - Industry Perspective
- Day Two
  - Technical Focus
  - Working Sessions
- Day Three
  - Working Sessions
  - Summary Wrap-Up

## SPACE STATION OVERVIEW

Mr. Andrew J. Stofan provided the Workshop an overview of the Space Station program. In Mr. Stofan's remarks, he stated the primary purpose for the Space Station program is to provide technology leadership in Space. Other points made during the presentation were:

- The key part of the Space Station will be the pressurized laboratories.
- There will be a minimum of five shuttle flights per year to the Space Station - this will provide the greater access to space required by the scientific community.
- The Station is being designed to be technology transparent so that during its 20-30 year life-span, it can be updated as technology progresses.
- The Space Station will be a place of opportunity for entrepreneurs and a place to conduct experiments.
- The largest technical challenge will be the assembly process - requiring 19 shuttle flights.
- The Space Station program presents a significant management challenge since it encompasses all of the NASA centers and international partners.
- The Space Station planned mid-1990's deployment is entirely budget-dependent.
- The Space Station program is international in scope. Agreements with the international partners are being negotiated and resolutions are expected by the end of 1987.
- The U.S. is no longer pre-eminent in the use of space. The Soviets have a vigorous program that exceeds the U.S. in some areas now and will completely do so in the near future.
- The Space Station design is driven by user requirements.
- National policy is to encourage commercial participation in the Space Station program.
- NASA has developed a set of guidelines for the commercial use of the Space Station.
- The Space Station program now enjoys strong Congressional support.





National Aeronautics and  
Space Administration

## SPACE STATION PROGRAM OVERVIEW TO THE SPACE STATION COMMERCIAL USERS WORKSHOP

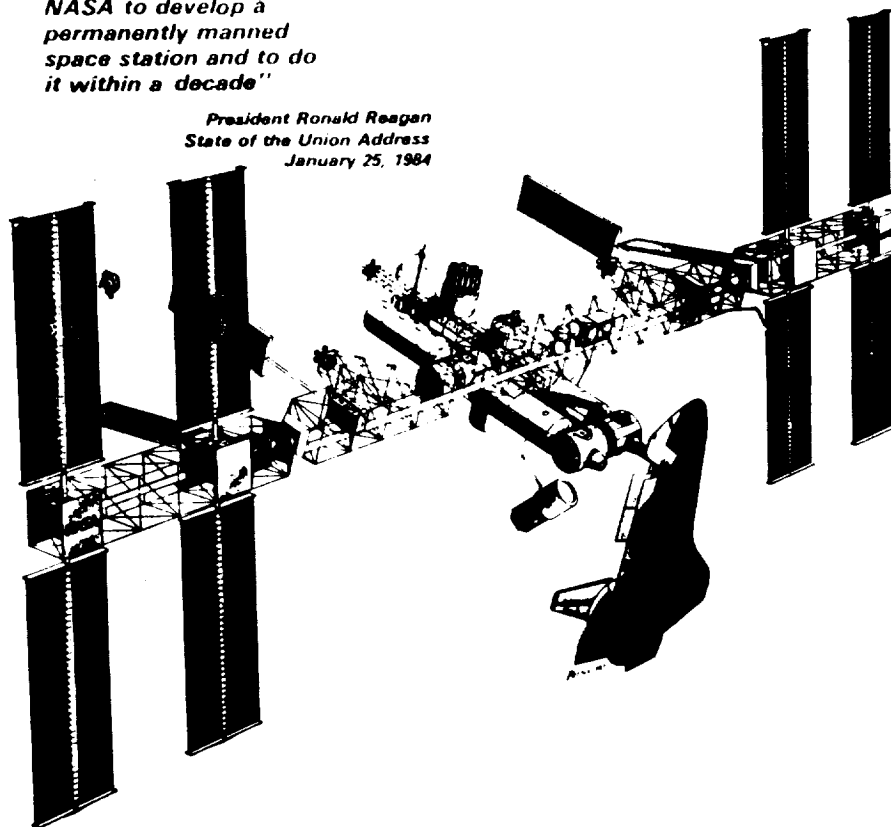
ANDREW J. STOFAN  
Associate Administrator  
for Space Station

NOVEMBER 3, 1987

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*"Tonight, I am directing  
NASA to develop a  
permanently manned  
space station and to do  
it within a decade"*

President Ronald Reagan  
State of the Union Address  
January 25, 1984



NASA HQ 50-  
REV 8-22



## THE SPACE STATION

---

### FOR SCIENCE AND TECHNOLOGY

- A research laboratory in space that is permanently manned

### FOR SPACE EXPLORATION

- A point of departure, an enabling capability for future missions

### FOR NASA

- A means in the future for the conduct of business

### FOR THE UNITED STATES

- An essential element of civil space policy
- A symbol of our commitment to leadership in space

### FOR MANKIND

- A first step towards living and working beyond the Earth

**SPACE STATION: A KEY TO THE FUTURE**

FILE NAME: S-SpaceSt

OSSTT 39G  
NASA HQ S 2-1-87



## A RESEARCH LABORATORY IN SPACE

---

STATION ELEMENTS	STATION ATTRIBUTES	DISCIPLINES ENHANCED
<ul style="list-style-type: none"><li>• Pressurized laboratories</li><li>• Structure for attached payloads</li><li>• Unmanned platforms</li></ul>	<ul style="list-style-type: none"><li>• Permanent presence</li><li>• Interactive crew</li><li>• Repetitive access</li><li>• High level of power</li></ul>	<ul style="list-style-type: none"><li>• Life sciences</li><li>• Materials processing</li><li>• Astrophysics</li><li>• Earth sciences</li><li>• Technology</li></ul>

FILE NAME: S-ResLabmSp

OSSTT-16F  
NASA HQ Rev. 5-30-87



NASA  
Space Station

## HOOKS AND SCARS FOR EVOLUTION

### THERMAL CONTROL SYSTEM

- Designed for modular replication
- Radiators and condensers can be added as needed
- Fluid lines and pumps sized for growth
- Line tees and capoffs planned for growth additions

### POWER MANAGEMENT AND DISTRIBUTION SYSTEM

- Power cables sized for growth and space provided for additional cables if more growth needed
- Connectors provided for additional bus switching units
- Space provided for additional switching/distribution units if required

### MECHANICAL SYSTEMS

- Berthing mechanism designed for growth by replication
- Power distribution and fluid joints sized for growth

### DATA MANAGEMENT SYSTEM

- Extra ports for network interface units, local area networks, subsystem data processors, multiplication consoles, etc.
- Margin in the memory and central processor unit time
- Parallel ports for addition of storage units
- Modular design

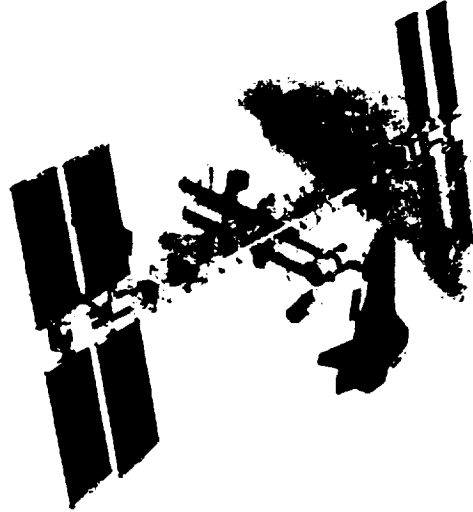
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NASA HQ 5-1-87



# SPACE STATION

- ENHANCE CAPABILITIES FOR SPACE SCIENCE AND APPLICATIONS
- STIMULATE ADVANCED TECHNOLOGIES
- PROMOTE INTERNATIONAL COOPERATION
- DEVELOP FURTHER THE COMMERCIAL POTENTIAL OF SPACE
- CHALLENGE SOVIET LEAD IN SPACE STATIONS
- CONTRIBUTE TO AMERICAN PRIDE AND PRESTIGE
- STIMULATE INTEREST IN SCIENCE AND ENGINEERING EDUCATION
- PROVIDE OPTIONS FOR FUTURE ENDEAVORS IN SPACE



**ASSURE FREE WORLD LEADERSHIP IN SPACE  
DURING THE 1990's AND BEYOND**

OSSTT-88C  
NASA HQ 587.47b.1  
5-28-87



NASA  
National Aeronautics and Space Administration

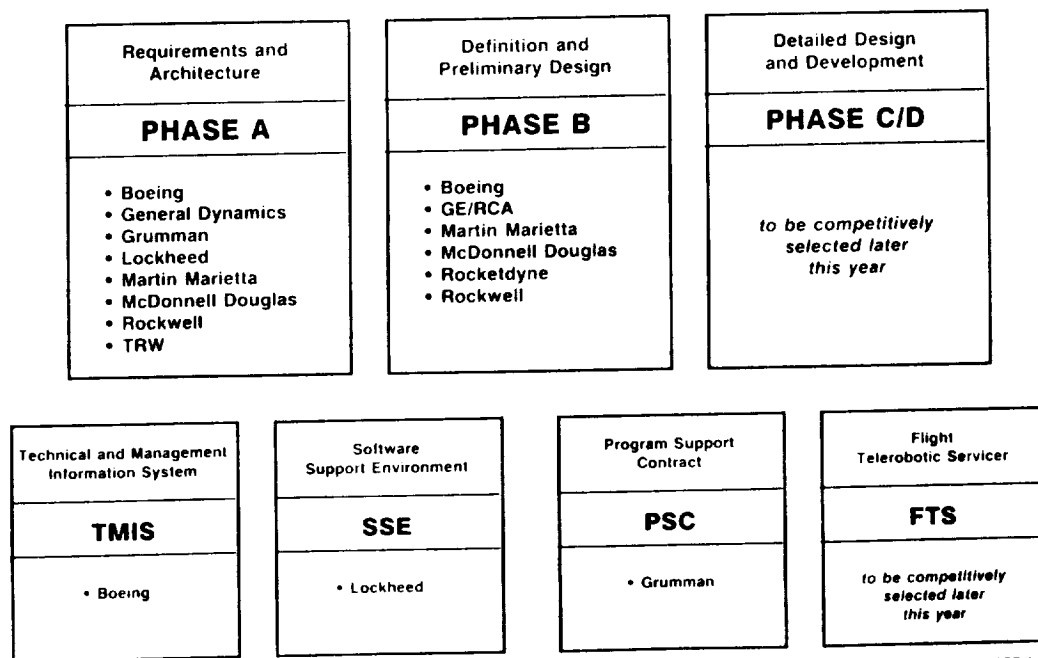
## SPACE STATION PROGRAM OBJECTIVES

- Develop a permanently manned Space Station by the mid 1990's
  - Provide useful and affordable capabilities
  - Enhance space science and applications
  - Help realize the commercial potential of space
  - Secure international cooperation
- 
- Design for evolution
  - Push automation and robotics technologies
  - Incorporate potential for man-tended concept in baseline program
  - Blend manned and unmanned systems and capabilities



NASA  
Space Station

## PARTNERSHIP WITH INDUSTRY



FILE NAME: SIPw/industry

OSSTT-64  
NASA HQ Rev. 7-29-87



NASA  
Space Station

## SPACE STATION PROGRAM

### UTILIZATION

- FROM THE START, PROGRAM FOCUSED UPON UTILIZATION
- USERS: SCIENCE, COMMERCE, TECHNOLOGY
- USER REQUIREMENTS HAVE HELPED SHAPE STATION DESIGN
- STATION WILL PROVIDE USERS WITH DIVERSE CAPABILITIES

FILE NAME: 8/85U1H

NASA HQ 5-Pe- 6-2-87



NASA  
Space Station

## SPACE STATION PROGRAM IS

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### INTERNATIONAL IN CHARACTER

- President Reagan invited international participation
- Extensive cooperation occurred during Phase B
- Formal negotiations nearing completion with ESA, Japan and Canada over cooperation during development and operations
- NASA is prepared to go it alone, if necessary

### A CIVIL ENDEAVOR

- DOD continues to have no requirements for a permanently manned Space Station
- DOD is not a program participant but may well use the Station in the future

### WELL BEHIND THE SOVIET PROGRAM

- MIR reflects strong Soviet commitment to Station
- What will the Soviets have in 1994?

FILE NAME S/SSProgIs

OSSTT-88C  
NASA HQ S 10-2 87



NASA  
Space Station

## PROGRAM SCOPE

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### SCHEDULE

January, 1984	President Reagan's directive to NASA
April, 1985	Preliminary design studies began
November, 1987	Target date for hardware start
March, 1994	First launch of Station hardware
Early 1996	Target date for full-time crew

### COST

- Late in 1986 NASA concluded a major review of Space Station Program costs. These costs were then reexamined early in 1987, at the request of the Administration
- NASA estimates the development cost of the Revised Baseline Configuration to be \$14.6 billion in FY 1988 dollars

FILE NAME S/PrScope

OSSTT-4  
NASA HQ S Rev. 8 23 87



NASA  
Space Shuttle

## **U.S. COMMERCIAL DEVELOPMENT ACTIVITIES**

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- NASA and national policies encourage private sector investment and participation in space
- NASA Guidelines for U.S. Commercial Enterprises for Space Station Development and Operations provide policy framework
- Office of Space Station and Space Industries, Inc., signed a Phase B MOU to exchange information on their respective programs. Discussions on cooperation during Phase C/D development underway
- Phase C/D RFP's promote commercial participation in the program
- Offers of private investment in Space Station development and operations are welcome

**AN OPPORTUNITY EXISTS FOR COMMERCIAL  
PARTICIPATION IN SPACE STATION**

FILE NAME S/SSCDA

OSSTT 38E  
NASA HQ/Rev. 5 29 87

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### **NASA GUIDELINES FOR UNITED STATES COMMERCIAL ENTERPRISES FOR SPACE STATION DEVELOPMENT AND OPERATIONS**

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- (1) NASA welcomes and encourages participation in Space Station development and operations by U. S. commercial enterprises which seek to develop with private funds Space Station systems and services.
- (2) NASA will entertain proposals for commercial development and operation of Space Station systems and services with the goal of achieving negotiated agreements between NASA and the enterprise.
- (3) Agreements shall be for specific services with responsibilities and interfaces clearly defined and shall be focused on achievement of objectives in specific time periods.
- (4) NASA will provide, where appropriate, incentives to the enterprise.
- (5) NASA safety standards will be applied where appropriate; standards such as reliability and quality assurance will be applied based on criticality to Space Station functions.

OSSTT 38C  
(1 of 2)  
Rev 11/26/86

**NASA GUIDELINES FOR UNITED STATES COMMERCIAL ENTERPRISES  
FOR SPACE STATION DEVELOPMENT AND OPERATIONS  
(Continued)**

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- (6) NASA will protect proprietary rights, and will ask for privately-owned data only when necessary to carry out its responsibilities.
- (7) U.S. commercial enterprises may, where appropriate, enter into agreements with NASA to receive technical assistance, including access to NASA data and facilities.
- (8) U.S. commercial enterprises will retain responsibility for sustaining engineering, operational support, financing and spare parts for their services.
- (9) U.S. commercial enterprises may offer their services to Space Station participants.

THESE GUIDELINES ARE DERIVED FROM NASA'S COMMERCIAL SPACE POLICY WHICH IMPLEMENTS THE COMMERCIAL INTENT OF PRESIDENT REAGAN'S NATIONAL SPACE POLICY. THEY ARE INTENDED TO PROVIDE A FRAMEWORK TO ENCOURAGE U. S. COMMERCIAL ENTERPRISE INVESTMENT AND INVOLVEMENT IN THE DEVELOPMENT AND OPERATION OF THE SPACE STATION.

OSSSTT 38 C  
(2 of 2)  
Rev 11/26/86

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**SPACE STATION AND THE COMMERCIAL  
DEVELOPMENT OF SPACE**

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- Successful utilization of Space Station should produce requirements and opportunities for additional space resources and services
- Private sector could provide some of these additional resources and services
- Industry, not government, should determine the commercial value of space

OSS 7972  
10 26 87





## PROGRAM PLAN

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- Gives strong voice to Space Station user communities
- Provides competition among U.S. aerospace industry
- Realizes meaningful international participation
- Welcomes private sector participation in development
- Allows for Station evolution
- Establishes a major effort in technology development
- Focuses early attention on operations
- Provides for external advice and counsel
- Centralizes program management and planning
- Provided credible cost, schedule and technical projections through extensive definition phase and major reviews
- Responds to both Congressional and Presidential direction

FILE NAME: S/ProgPlan

OSSTT-11B  
NASA HQ SF 10-27-81





## OFFICE OF COMMERCIAL PROGRAMS

Mr. James T. Rose, Director, Office of Commercial Programs, NASA-HQ, provided the Workshop with an overview of NASA's efforts in the space commercialization program. The key points of the presentation were:

- NASA has developed a formula for allocating secondary payload space to the various users on the Space Shuttle. Commercial programs will receive 28% and the Office of Space Sciences and Applications will receive 38%. This will give the users the ability to better plan what experiments they can and cannot do. Approximately 2.5-3 times the lab space provided in SPACELAB will be available over the next few years.
- NASA will soon officially announce a significant increase in the down payload capability of the Shuttle which will add to the amount of secondary payload that can be carried.
- NASA will look to the 16 Centers for the Commercial Development of Space (CCDS) for new and innovative things to do in space that can lead to Joint Endeavor Agreements and hopefully into viable commercial ventures.
- NASA is setting down a set of new initiatives to build upon earlier policies and provide for new and vigorous post-51L Space commercialization program. NASA's Commercial Program Office will:
  - Form an industry advisory committee that will provide regular input on a broad range of space commercial issues including recommendations on space research priorities and generic equipment to support those companies seeking to test materials in NASA furnished equipment.
  - Develop and recommend a new pricing policy for use of Government transportation and on-orbit services by emerging commercial ventures. The policy is planned to encourage the use of NASA space equipment rather than discourage its use.
  - Develop a plan to manage and optimize the allocation of commercial secondary payloads on board the Space Shuttle and guidelines for users that can enhance the chances for flight opportunities.
  - Streamline the process by which companies negotiate and settle on formal agreements with NASA for cooperative space activities.
  - Expand the Small Business Innovative Research (SBIR) program in the Office of Commercial Programs to provide new opportunities for the small business entrepreneurs.
- Mr. Rose asked the Workshop attendees to consider what their Space Station support requirements would be if they were to conduct a development program which encompassed multiple testing, moving into a pilot production, and finally into a commercial program.



## INDUSTRY PERSPECTIVE

Mr. Edward Donley, chairman of the Executive Committee of the Board, Air Products and Chemicals, Inc., and Chairman of the Business-Higher Education Forum addressed the Workshop on the industry perspective to space commercialization. In prepared remarks, Mr. Donley expressed the following points:

- "The time has come to view space through a new national lens. It is not just the next frontier...it is the next competitive arena."
- "There is considerable potential for a non-aerospace company to grow and prosper from space technology -- as well as help strengthen the nation's competitive posture at the same time."
- "Technology transfer from space development has had far-reaching impacts on industrial and consumer markets."
- "American business is not so much risk-adverse as it is oriented to short-term results. Given the global competitive environment, future success in space will come only when industry and government collaborate on the three "P's" -- policy, pump-priming and patience. Government is the key."
- The recommended necessary roles of industry, government, and the university community include:
  - a company must have a sustainable, longer-term commitment to space research programs...and this commitment must span the senior management group and permeate to the depths of the organization.
  - a company must possess an exceptional capacity to innovate...and be quick to recognize potential uses of space activities that take advantage of its current skills base.
  - a company must approach commercial space development with a pioneering and entrepreneurial spirit...and a degree of "faith" that the pursuit will lead to new, profitable activities.
  - government must establish consistent and enduring policies that are at once coherent, but separately targeted to the growing needs of military, scientific and commercial space programs.
  - government must encourage joint ventures and other consortium-type arrangements...and foster private sector investment in space.
  - education institutions must continue to establish centers dedicated to developing bedrock space-related science, technologies and business skills--and to expand their roles in basic research and collaborative technology development.



Business-Higher  
Education Forum

**SPACE - THE NEXT COMPETITIVE ARENA**

**An Address By**

**Edward Donley**

**Chairman**

**Business-Higher Education Forum**

**and**

**Chairman**

**Executive Committee of the Board of Directors  
Air Products and Chemicals, Inc.**

**Before The**

**SPACE STATION COMMERCIAL USERS WORKSHOP**

**Nashville, Tennessee  
November 3, 1987**

Sputnik went into orbit in the fall of 1957. America leaped into action to make space exploration a national priority. During the intervening 30 years we have accomplished many of our original goals. In the process, we reaped many unexpected rewards -- and created new agendas for further pioneering and innovation in that seemingly boundless domain.

Yet today, America's leadership in space is in danger. Ironically, it is threatened more by the new economic competitive challenges here on earth than by the physical limits -- or financial demands -- imposed by that far frontier.

As an industrialist, I have witnessed the spin-offs from space development that have given rise to great commercial success. Our company, Air Products, rose from a small specialist to a two billion dollar enterprise. A significant portion of the company's business derives from the lessons learned in space development and transferred into a 12 billion dollar commercial market for industrial gases worldwide.

In the Business-Higher Education Forum, we have focused many years on the deterioration of the United States' ability to educate, to invent, to produce and to market competitively in the international economy. The Forum helped alert the nation to this crisis. We don't yet have fully developed solutions.

I have reached several conclusions.

First, our lead in space is endangered by competition from other nations. The European Community, the Soviet Union, Japan, and China all have long-range, government-directed programs to enter, or expand, their share of the space arena. Our space program was long spurred by government for national purposes. We cannot exploit the commercial opportunities of space in the future without a continuous stimulation by our government.

Second, proceeding in commercial development of space requires different approaches and relationships than in the past. In part, that is because commercial goals are tied to different economic rules -- but, also because those rules are themselves being tightened and transformed by fierce new global economic competition.

And, third, we cannot afford to lose the opportunities that space commercialization provides to our long-term competitiveness. Leadership in space has been characterized by technological superiority. For the future, space leadership will increasingly fall to those who have the imagination and the will to convert the technological possibilities into competitive realities. It means new knowledge, new skills, new jobs, and new uses for both people and machines.

This does not mean that we should abandon the pure research in outer space, or narrow the perspective on scientific inquiry. On the contrary, that must, and will continue.

Space must be viewed through a new national lens. It is not just the next frontier ... it is the next competitive arena.

Space presents a new environment that promises the commercial development of new materials and new processes, new services -- particularly technical services -- and an expanded view of the universe. We need a dedicated, collaborative effort among government, industry and our universities that will lead the U.S. to new achievements in space -- and new leadership in the world's competitive order.

American industry's attraction to space has changed dramatically over the past three decades. We need to understand those changes if we are to foster development of the highest potential commercial applications. We also need to establish firm public and private policies that outline the ingredients necessary for the commercial success of American space activities.

We have come a long way since our first space probe in 1958. From Explorer I through the Space Shuttle, there has been a steady growth of technology transfer and commercial development. Space exploration profoundly changed our concepts and



applications for communications, transportation, and a variety of other fields.

Names like Mercury, Apollo, Mariner, Pioneer and Skylab were milestones in astronomy, physics and materials processing. A manned presence in space was assured, and with it new laboratories for research were powered by the sun and lit by the stars.

These "enterprises" rewarded their investors -- the American taxpayers -- with more than prestige. They produced knowledge and commercial benefits that worked their way into our lives in direct ways.

Scientists and engineers did remarkable things. A thriving aerospace industry bloomed under effective program management and large-scale systems integration. But it is important to remember that government was always in the lead -- with both policy and pocketbook.

Yet, for the moment, the potential benefit of space development eludes us. The time scale for profit is different when private capital is at risk. Shareholders and taxpayers respond to different investments. They measure results by different standards.

There is considerable potential for non-aerospace companies to grow and prosper from space technology -- as well as help strengthen the nation's competitive posture. To illustrate this point, I will briefly trace the experience of Air Products and Chemicals, Inc.

In the mid-1950s, liquid hydrogen was little more than a laboratory experiment. The U.S. Air Force was studying hydrogen for several applications. Hydrogen's high energy content was well known, but in its normal gaseous state, it could not be used in flight vehicles. Air Force sponsored research resulted in processes for liquefying hydrogen to reduce the volume. Another problem remained however: liquid hydrogen was available only in laboratory amounts -- grams per day. The ambitious Air Force programs would require testing in flight quantities in tens of tons per day. Air Products undertook the challenge of developing processes for the large quantity production of liquid hydrogen.

In roughly three year's time, the company scaled up liquid hydrogen production from grams to 30 tons per day. Over this short period, Air Products demonstrated the feasibility of large-scale liquid hydrogen production, incorporating different technologies, and different feedstocks. Subsequently, Air Products constructed three more liquid hydrogen facilities to supply NASA's growing Space Shuttle requirements.

Thus, from 1957 through the present, Air Products grew to be an integral part of the nation's space transportation infrastructure by supplying liquid hydrogen used on the Saturn V launch vehicle that sent the Apollo astronauts to the moon and for the Space Shuttle program.

In the process, the company not only pioneered the development of hydrogen production processes, but also developed much of the distribution, storage and handling procedures required for the safe use of liquid hydrogen at various test and launch sites. Its continued commitment to hydrogen R&D and safety reduced the cost of producing hydrogen and thus opened large new commercial markets for the product.

In 1981, Air Products opened the first facility solely dedicated to supplying the needs for the non-government users. Today, liquid hydrogen is widely used -- by petroleum refineries, chemical and pharmaceutical firms, food processors, metal alloy producers, electronic companies, electric utilities -- and by many other basic and higher technology industries whose applications are growing at more than twice the rate of the United States GNP.

These applications did not appear overnight. Many came out of the applied research laboratories of the industrial gas industry. From virtually zero in 1960, today's market for liquid hydrogen in non-aerospace applications is more than

four times the current demand from government programs. And, private capital has long since replaced the government support for this new growing industry.

This story exemplifies the technology transfer process in aerospace. Space needs, originally military and subsequently NASA, created a large market for a new product. Air Products rose to the challenge and, with government funding, perfected the technology. This launched the private sector expansion into many non-government applications with obvious benefits to the nation and the corporation. The U.S. is currently the world's acknowledged leader in liquid hydrogen technology and its application.

These commercial benefits don't just happen. They require management commitment over a long period of time and the efforts of many innovative, dedicated people. NASA can cite many similar stories of technology transfer that have had far-reaching impacts on industrial and consumer markets.

But times have changed, and we must recognize the fundamental differences between the operating conditions 30 years ago and those of today. Let's compare the two environments for the commercialization of space-related technologies.

Previous space programs were policy-driven with space-related achievements as the primary focus. The current space commer-

cialization program, however, is focused directly on achieving business success through the private sector, seeking large up-front capital and human resources. In earlier years, the private sector was the spin-off benefactor. Now, the focus of the initiative itself is on the commercial applications, mandating a more definitive business strategy.

Nowadays, the stakes are not only different -- but considerably higher. Information is disseminated much faster and technology developments are accelerated wherever possible to gain competitive advantage. The technology transfer time is much more critical now. A mere decade ago it was much less sensitive.

Previously, technology transfer from space-related programs was from government applications to the private sector. Today, space-developed products are directly dependent upon specific potential ground-based markets.

Finally, the competition today is worldwide. There are major space programs underway in Europe, the Far East and, of course, the Soviet Union. Parallel technology developments across more than one space program can lead to intense international competition for the introduction of a technology into the private sector.

More than anything, these differences tell us that the federal government, industry, and the university community must work more closely together than ever to facilitate the successful commercial development of space. Private sector benefits of space-developed technologies -- seeded by government funds -- can still occur in a serendipitous manner.

We need an agenda for the commercial success of space that joins our private and public sectors in a dynamic partnership.

First and foremost, the company must have a sustainable, longer-term commitment for the space research program. This is particularly true for materials processing, and also true for such disciplines as remote sensing and communications. This commitment must span the senior management group and permeate to the depths of the organization.

Additionally, the company must possess an exceptional capacity to innovate. It must be quick to recognize the potential uses of space activities that take advantage of its current skill base. Without this, the company will not have the foresight to envision the space-derived applications that could differentiate it from others in the marketplace.

A pioneering and entrepreneurial spirit are essential ingredients for any organization which elects to pursue highly

complex and technical space initiatives. There has to be a degree of "faith" that the pursuit of space will lead to new, profitable activities.

And, the organization must be knowledgeable about space. If not, it must be willing to develop the knowledge and the tools required to successfully undertake space commercialization efforts.

Finally, the organization must be confident that policies of the United States Government will be in place over a time frame commensurate with the private investment risks.

If an organization does not have these attributes, it should not seriously consider development of space-related activities.

The federal government has an equally challenging role to play in this new space endeavor.

Foremost, the government must establish consistent and enduring policies. They provide the backbone for the decision-making process that must proceed in the private sector. Corporate management needs the predictability that permits space ventures to compete successfully against ground-based ventures. Without these policies, U.S. commercialization of space will not go forward.

Next, the government must provide the necessary physical infrastructure within which the commercial development of space will take place. At a minimum, this must include cost-effective space transportation systems and space research platforms.

The space activities of the United States must be framed against a coherent, yet separately targeted, set of space policies. No longer can a single, simplified U.S. space policy address all the issues on a growing spectrum of military, scientific and commercial programs.

Government must facilitate the development of commercial activities. This should take the form of encouraging joint ventures and other consortium-type arrangements. It requires that government foster private sector investment in space. And, government must also develop intellectual property protection and provide for adequate insurance coverage in the early years of a successful commercial development program.

We must remember that the operating environment of American business is very different from that which exists in other industrial nations. American portfolio managers demand shorter-term results than do their counterparts elsewhere. This is a fact of life.



American business is not so much risk-averse as it is oriented to short-term results. Given the global competitive environment, future success in areas like space development will come only when industry and government collaborate on the three "P's" -- policy, pump-priming and patience.

Government is the key.

Last, but not least, the university sector is a vital participant in the successful commercialization of space.

Educational institutions must continue to establish centers dedicated to developing the bedrock space-related science, technologies and business skills. In the academic community, we must maintain and expand our role as a forum for basic research efforts and for collaborative technology development.

And finally, we must establish curricula and foster an innovative training environment for scientific, technical, business and other disciplines critical to developing the human capital to lead this nation's space activities for generations to come.

I salute NASA's efforts to truly understand the potential for the commercial development of space and to define the potential commercial applications of the Space Station. This workshop is a tangible expression of that commitment. I encourage all visionary private sector organizations to

examine the space potential for expanding existing products and services. Most of all, I look to federal government policymakers to increase -- even in these deficit-plagued times -- the funding for space. Without this leadership role, the United States will not be competitive in the space arena by the turn of the century.

Those of you from private industry gathered here form the nucleus of the future commercial space industry. I know that you will face difficult and anxious questions in making very risky decisions. Changed conditions have magnified the risks. But, some things don't change. Among them are the dreams of the pioneer and the instincts of the entrepreneur. I hope you will trust them both at the right time.

Being competitive in space can be a key to improved American economic competitiveness around the world. Both are long-term propositions. Both are on the launch pad right now ... and counting.

Thank you.



## QUESTION AND ANSWER SESSION

### STOFAN, ROSE, AND DONLEY

Mr. Stofan, Mr. Rose, and Mr. Donley entertained the following questions from the Workshop attendees:

Q: When will the already approved JEA's in the materials processing area be manifested [on the Shuttle]?

A: (Rose) They are in the process of being manifested. The experiments are being prioritized so that those that have the best chance for early commercialization activity will fly initially. I expect to have a better idea of the manifest in about a month [Dec. 1987].

Q: What has kept NASA from revitalizing the Skylab and Saturn V programs as interim space ventures?

A: (Stofan) Both the Skylab and Saturn V are obsolete and represent 25-30 year old technology. It would require essentially the same effort to revitalize those programs as it would to design and build new systems.

Q: Please elaborate on the STS down weight increase.

A: (Rose) The increase has gone through the Space Shuttle change board. NASA will announce the increase through press releases. The increases are significant enough that the Office of Commercial Programs has begun planning for them.

Q: What should the proper role of Government be in encouraging the commercial space development?

A: (Donley) Government should provide the seed money so that the commercialization of the technology is close enough to realization that the private sector capital can be drawn out of the capital pool of the country. Otherwise only those research efforts which aim at on-ground, short-term commercial developments will get the human resources and capital resources and the longer-term projects will not be developed.

## ATTRIBUTES OF SPACE

Dr. E.A. Brown, Boeing Aerospace Corp., presented a briefing on the technical attributes of space. The briefing discussed understanding or using the following attributes and environments of space:

- The **extraterrestrial vantage point** from which to observe Earth, the solar system, and the stars.
- The **microgravity** environment in materials processing.
- **Solar radiation** outside the atmosphere and unaffected by absorption by atmospheric constituents.
- The **high-vacuum** characteristics of space to create even higher vacuums for a variety of uses.
- The **residual Earth atmosphere** found in low earth orbit.
- The **charged particles** in the Ionosphere.
- The **Earth's magnetic field** to generate power.
- The **ionizing radiation** in growing Microorganisms.
- The **meteoroid and debris** environment and their potential effects on systems.

## Attributes of Space



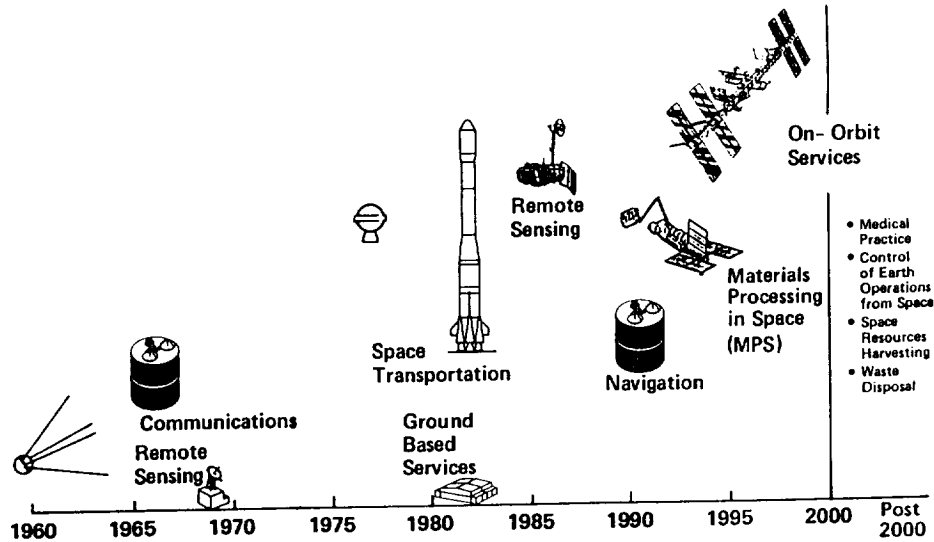
Boeing  
Peat Marwick

# Introduction

## Evolution of Commercial Space



Boeing  
Peat Marwick



## Attributes of Space



Boeing  
Peat Marwick

A unique environment.

- An opportunity for commercialization.
- A challenge to the designer.

## Attributes and Environments of Space

This chart shows the nine attributes and environments of space at low earth orbit altitudes. Each is described and discussed in more detail in the remainder of the document.

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## Attributes and Environments of Space



Boeing  
Peat Marwick

- Extraterrestrial vantage point
- Microgravity
- Solar radiation — high/low temperature
- High vacuum
- Residual atmosphere
- Ionosphere
- Geomagnetic field
- Ionizing radiation
- Meteoroids/debris

## Extraterrestrial Vantage Point

Spacecraft in earth orbit provide a useful extraterrestrial vantage point both for downward earth observation and outward astronomical observation.

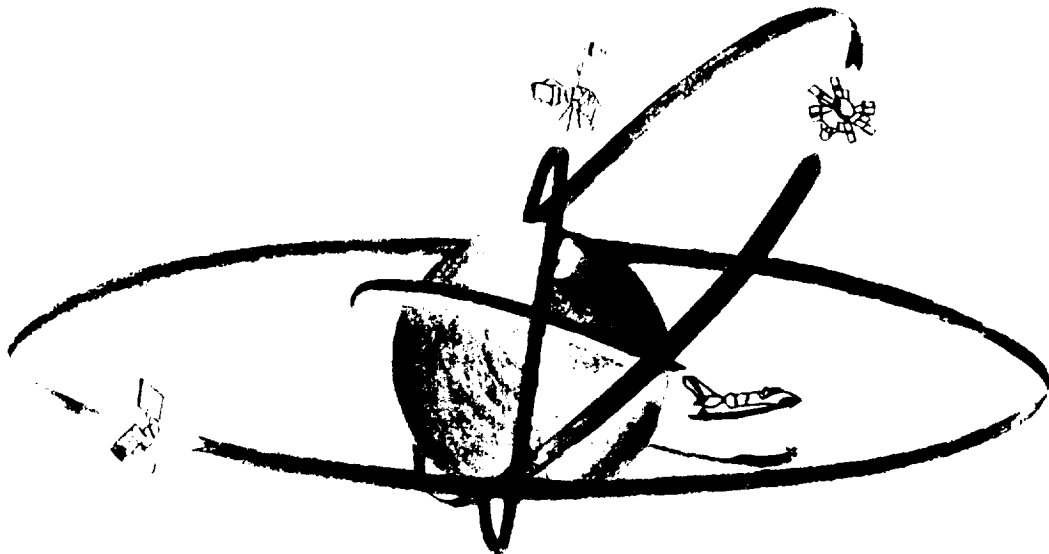
Satellite launches from NASA'S Kennedy Space Center are nominally at inclinations of  $28.5^\circ$  and  $57^\circ$  to the equator and are not suitable for polar observation. Launches are made into polar orbit from Vandenberg Air Force Base. These polar orbits include sunsynchronous (dawn/dusk) orbits that permit continuous daylight observation. Molnyia orbits are highly eccentric ellipses that provide extended viewing periods near apogee (the highest point). Geosynchronous orbits at a height of 6.6 earth radii provide continuous coverage of a global hemisphere, but provide poor viewing of polar regions.

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## Extraterrestrial Vantage Point



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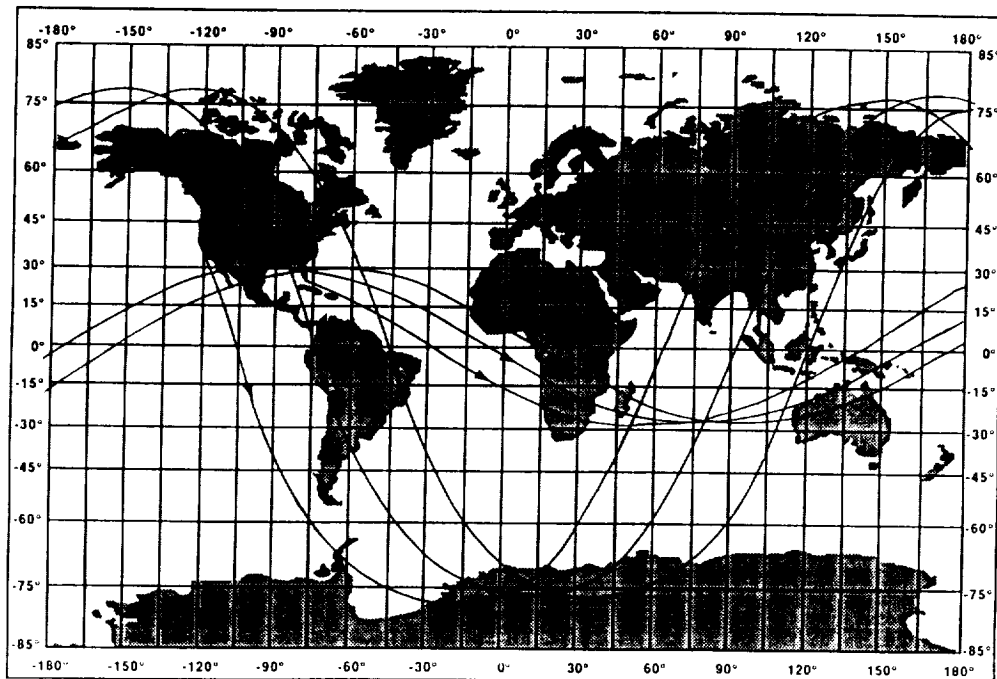
## Satellite Ground Tracks

The chart shows the ground projections for two orbits. One is the typical ground track coverage of a low inclination ( $\sim 30^\circ$ ), low altitude satellite which allows passage over the same area every seven orbits ( $\sim 10.5$  hours). The other ground track is for a near polar sunsynchronous satellite in a high altitude circular orbit ( $\sim 1690$  km altitude,  $102^\circ$  inclination) it provides coverage of the same area every six orbits ( $\sim 12$  hours).



## Satellite Ground Tracks

Boeing  
Peat Marwick





## Uses of Extraterrestrial Vantage Point

The chart lists the four major uses of the earth orbit vantage point.  
An example of each is given in the next four charts.



### Use of Extraterrestrial Vantage Point



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Peat Marwick

- Communication relay node
- Earth remote sensing
- Solar/stellar observations
- Navigation node

## Telemetry Data Relay System (TDRS)

Many low-altitude satellites are not in radio contact with friendly ground stations for most of their orbits. The Telemetry Data Relay System (TDRS) satellites at geosynchronous locations provided global coverage of satellite positions.

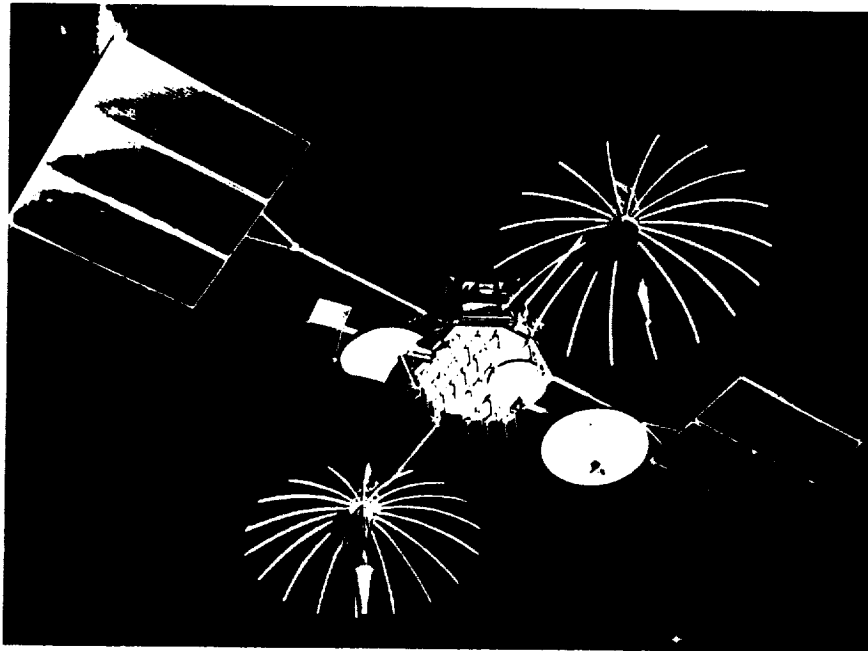
The satellites have a communication system which can relay mission commands and telemetry data between all satellite locations and continental U.S. ground stations continuously.

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## Tracking & Data Relay Satellite (TDRS)



Boeing  
Peat Marwick



## Earth Remote Sensing Evolution

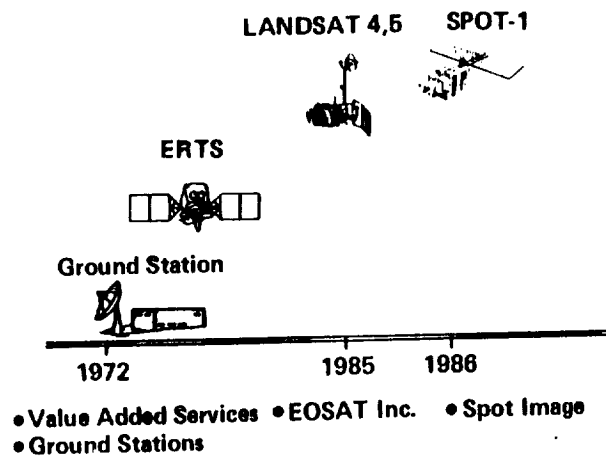
The chart shows the evolution, past and predicted, in earth remote sensing by satellites. It shows the development of satellite ground stations in the 1970's, the United States Landsat Earth Resources satellites, and the recently launched French SPOT satellite. Predicted for the 1990's are synthetic aperture radar satellites and large platforms typified by the proposed NASA Space Station.

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## Earth Remote Sensing Evolution



Boeing  
Peat Marwick



# Earth Remote Sensing Evolution



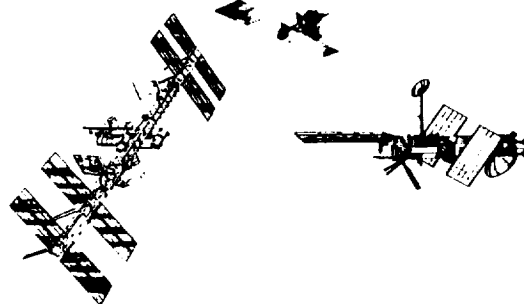
Boeing  
Peat Marwick

- Radar Sensors

- Space Station

- Large Platforms

RADAR SAT  
ERS-1  
JERS-1



1987

1991

1993

1995

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## Civilian Earth Remote Sensing Missions



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Peat Marwick

- Meteorological
- Earth resources
  - Agriculture and forestry
  - Hydrology
  - Geology
  - Land use mapping and planning
  - Environmental monitoring
  - Marine and ocean resources
- Search and rescue

## Hubble Space Telescope

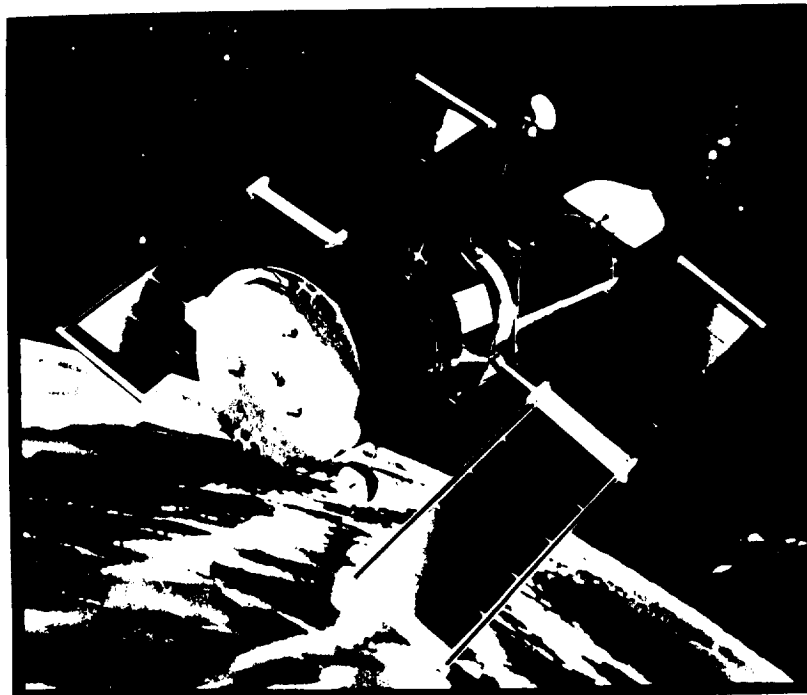
This viewfoil depicts an artist's concept of the fully deployed multipurpose Hubble Space Telescope with the Shuttle nearby. The telescope has a TV type recording system with much more sensitivity and dynamic range than photographic films and is capable of observing celestial sources 50 times fainter than the most powerful telescopes on the ground.

The telescope system will enable Man to piece together much more of the puzzle of the universe: how it began, how it grew, how it is changing, and how those changes affect Earth. Its unique capability for sharply defined imagery without atmospheric interference allows scientists to gaze seven times farther into space than ever before, possibly to the edges of the visible universe.

The telescope will be remotely operated by scientists on the ground through a television-type pointing and recording system. Several optical sensors, located in the instrument bay behind the primary mirror, share the concentrated light collected from celestial sources. The instruments are modular so that modifications, repairs, or replacements can be performed by astronauts.

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## Hubble Telescope



Boeing  
Peat Marwick

## Navstar Satellite Navigation System

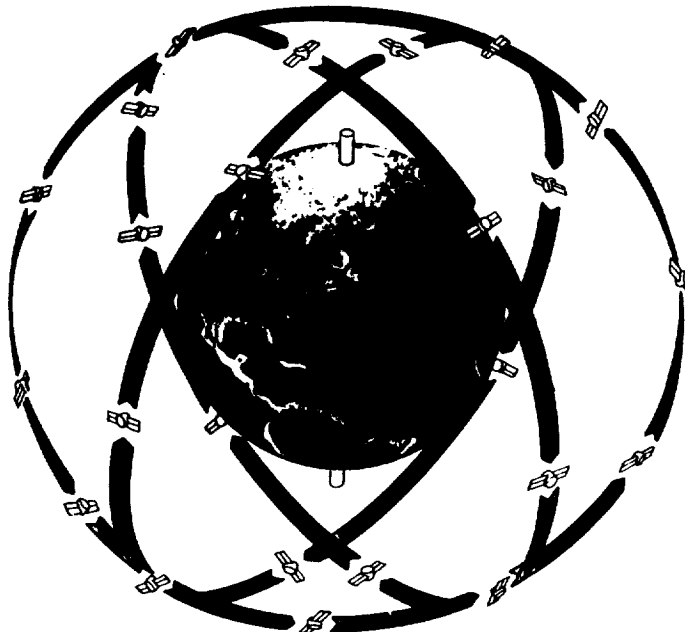
The U.S. Air Force is planning to establish a network of 18 Navstar Satellites for surface navigation. The satellites will be in three separate polar orbits (6 per orbit) at an altitude of 11,000 miles. From these orbits they will beam radio signals continuously to allow any one on the surface of the earth with a radio to determine his position accurately to within tens of feet.

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## Navstar Satellite Navigation System



Boeing |  
Peat Marwick



## Microgravity

Microgravity conditions in spacecraft create unique opportunities for experiments. All objects in orbit are in free fall and have no apparent weight. There are no convection or buoyancy effects in gases or liquids. The use of small thrusters to control the attitude and position of a satellite introduces effective gravitational forces. On manned missions there will be somewhat more gravity due to astronaut movement.

In the picture astronauts Carr and Pogue demonstrate superhuman strength in their pose. This weightless freedom actually inhibits astronaut performance for some tasks requiring application of external forces. Candle flames demonstrate the lack of air convection in a weightless atmosphere where hot combustion gases are not driven upward by heavier cold gas below. Such lack of convection and buoyant separation allows growth of much larger and more uniform crystals such as mercuric iodide shown here.

---

## Microgravity



Boeing

Peat Marwick



1q  
Physical Chemical  
Processes



0q



Near-Weightless



Material  
Processes

## Physical Processes Affected by Microgravity

Microgravity results in the weakening of natural phenomena such as convection, sedimentation, buoyancy, hydrostatic pressure, and the necessity for container walls. The removal of these phenomena has a significant impact on many aspects of the processing of materials and on scientific research in areas such as studies of combustion and fluid transport phenomena.

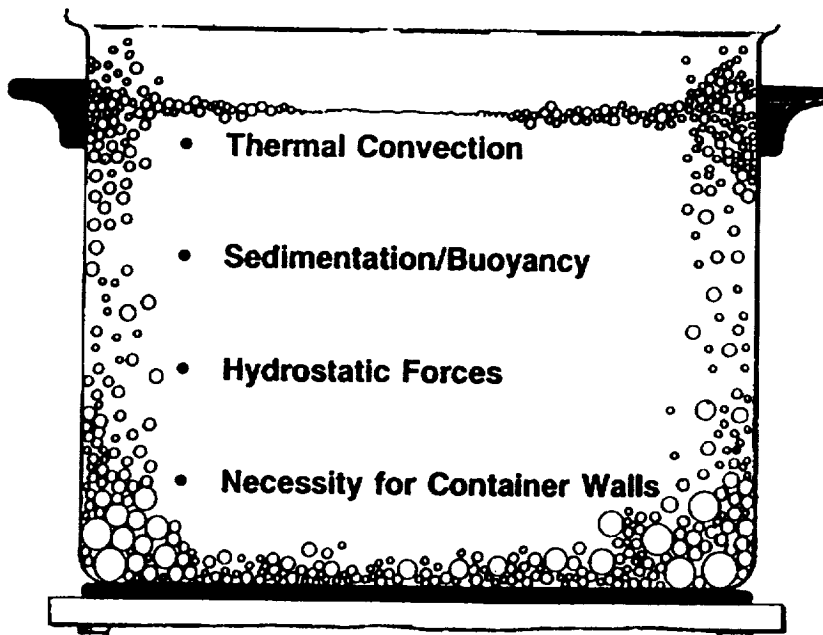
There are large uncertainties in the current understanding of microgravity phenomena and a strong research foundation must be built for commercial applications.

---

## Physical Processes Affected By Microgravity



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## Vapor Crystal Growth in Microgravity

Microgravity conditions enhance the quality of manufactured crystal products. Experiments on Shuttle produced significantly larger and higher quality crystals.

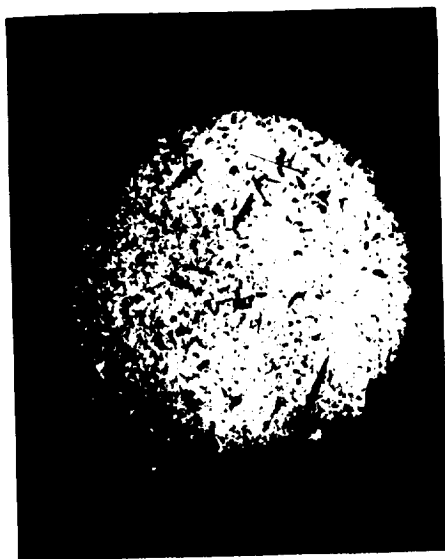
Vapor crystal experiments in space have produced surprising and unexpected results. The flight samples had loose, web-like structures of large platelets. These experiments also produced thin crystals that grew in the gas atmosphere instead of on the ampoule wall. Some of the crystals were significantly larger than those produced on Earth; for example, one of the space-grown crystals was about 20mm by 10mm. Also, the experiment samples make it very clear that the more uniform microgravity growth conditions have a beneficial effect on surface and bulk morphology; for example, the defect density is lower (about 1% of ground-based processing) and the samples have much better planarity.

---

## Vapor Crystal Growth in Microgravity



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a

(A) GROUND BASED



b

(B) SPACE

## Summary Materials Processing in Space

Applications of the microgravity environment can be categorized by scientific discipline, by process, by type of experimental or production facility or by end product (research results or physical products).

The accompanying table was abstracted from the Microgravity and Materials Processing Facility (MMPF) contract report and represents an approach which combines some of these methods of categorization (the MMPF study is an ongoing contract effort sponsored by Marshall Space Flight Center and performed by a Teledyne Brown Engineering/Boeing team). The discipline areas shown form the basis for the definition of experimental facilities for the U.S. Laboratory Module of the Manned Space Station.

## Summary Materials Processing in Space



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Discipline	Experiment
Bioprocessing	Collagen Processing Continuous Flow Electrophoresis Isoelectric Focusing Protein Crystal Growth
Electronic Materials	Directional Solidification Electroepitaxial Crystal Growth Float Zone Crystal Growth Solution Crystal Growth Thin Film Crystal Growth Vapor Phase Crystal Growth
Glasses and Ceramics	Acoustic Containerless Processing Glass Fibre Pulling High Temperature Glasses
Combustion	Autoignition Studies Droplet Burning Premixed Gas Combustion Solid Surface Burning
Fluids and Transport	Cloud Formation Microphysics Critical Point Phenomena Free Surface Phenomena Thermophysical Properties
Metals and Alloys	Electromagnetic Containerless Processing Eutectoid Alloy Solidification Foam Metals Solidification of Immiscible Alloys Undercooling/EM Effects
Polymers and Chemistry	Membrane Production Monodisperse Latex Spheres Transcrystalization in Thermoplastics Zeolite Catalyst Production

## Spectral Distribution Curves Related To The Sun

The solar irradiance at satellite altitudes is higher than at sea level because there is no atmospheric absorption or scattering. Above the atmosphere the average power level from the sun is  $1390 \text{ watts/m}^2$ . The distribution over the wavelength range is shown in the chart. The curve for a black body radiator at  $5900^\circ \text{K}$  is also shown. There is a seasonal variation of approximately  $\pm 3\%$  due to changes in solar distance from summer to winter.

The solar irradiance at sea level is reduced by about 25%. The absorption bands, shown in the chart are primarily due to water vapor, carbon dioxide and ozone.

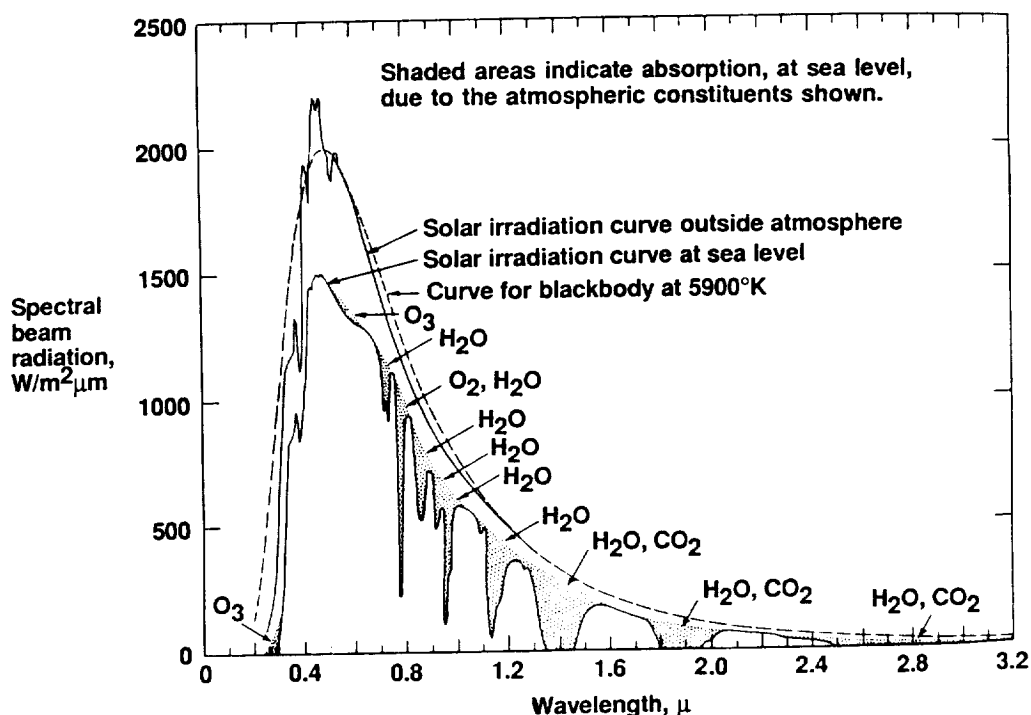
Solar irradiance is a major driver in spacecraft design. Configuration of solar cell arrays for electric energy production, thermal insulation blankets and cooling radiators for internal heat control, and exterior instrumentation of all kinds must be designed to accommodate solar energy.

## Spectral Distribution Curves Related to the Sun



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## Solar Furnace

Material processing furnaces require large energy sources that are hard to maintain in space. Concentration of solar energy provides a convenient and potentially continuous source of furnace power. High concentration ratios are essential so large optics are required.

The theoretical maximum temperature obtainable is approximately 5900°K (equal to the black body temperature of the sun). In practice however, thermal losses will determine the operating temperature. Soviet rocket experiments with 300 fold concentration have provided temperatures of several hundred degrees centigrade. Most low earth orbits, except for the special case of sunsynchronous orbits, will require continuous reorientation of the optical concentrator system to compensate for satellite motion.

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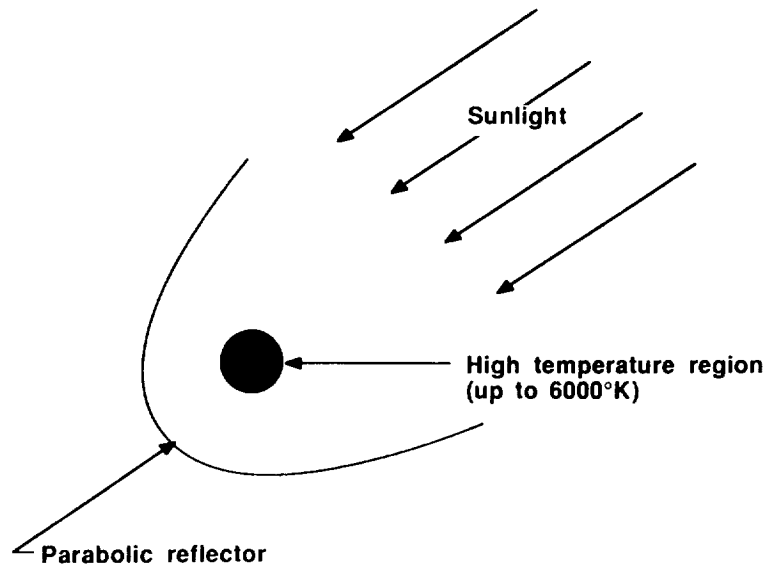
## Solar Furnace



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High temperatures readily available using solar furnaces



## Low Temperature Deep Space

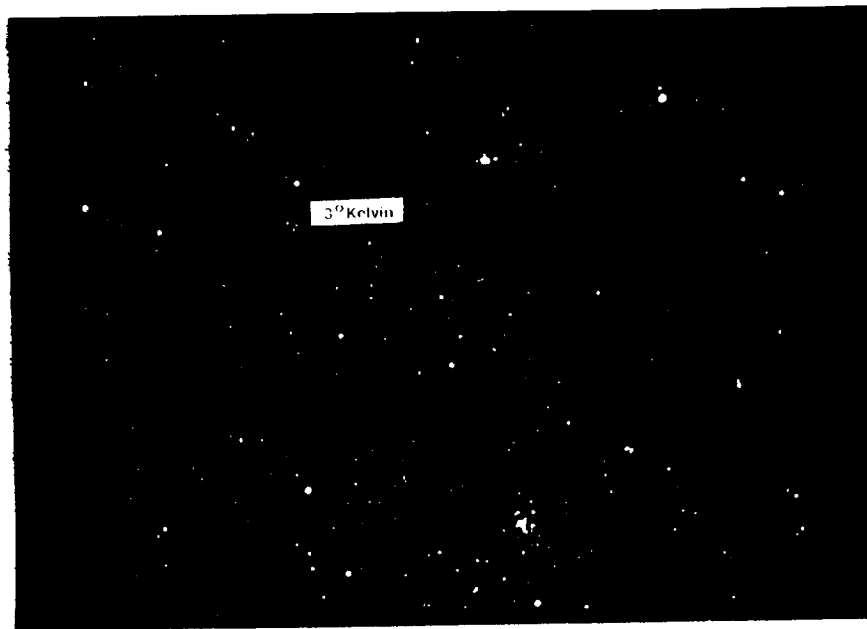
The universe has background temperature of 3° Kelvin or -454° F. If one looks away from the Sun and the Earth, this cold background predominates and can be used as a low temperature reservoir or heat sink. The background acts like a 3° K black body radiator with a predominant wavelength at 1 millimeter although the radiation has components at other wavelengths. It is temporally constant and extremely isotropic (uniform in all directions) and can be used to calibrate radio frequency (RF) receivers.

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## Sagittarius Star Cloud



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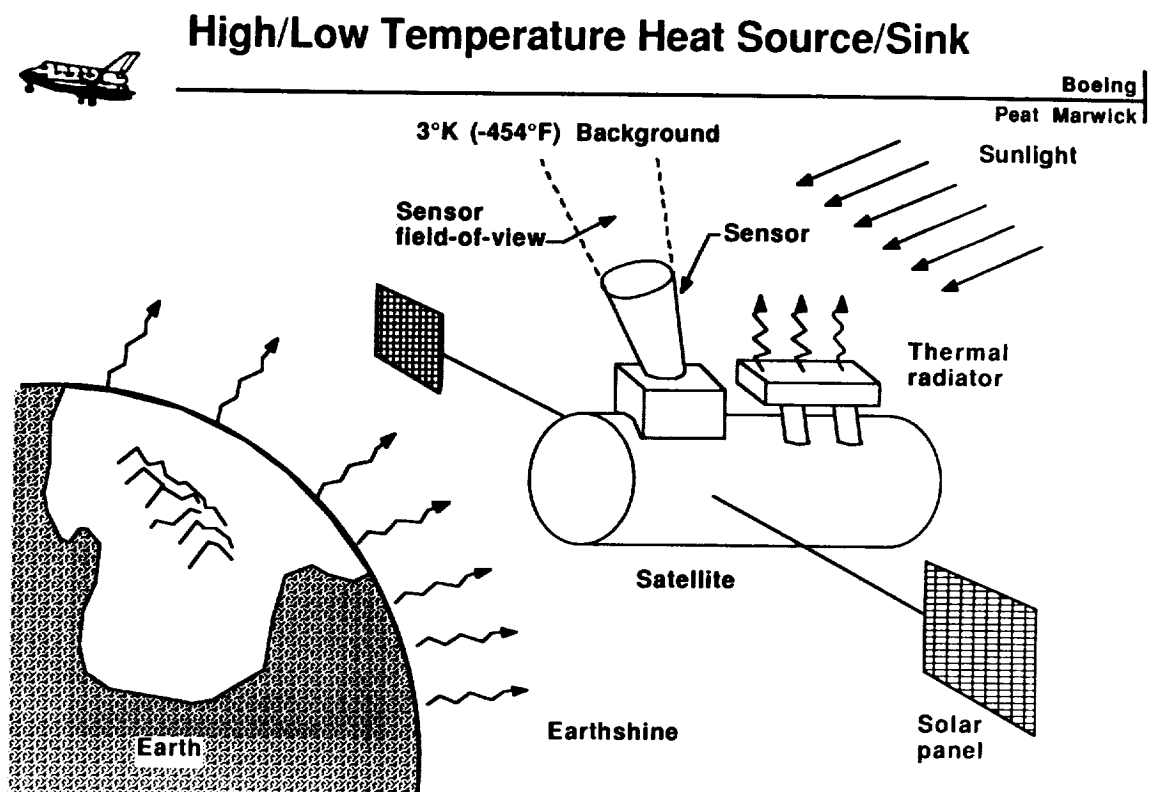
## High/Low Temperature Heat Sink/Source

A combination of the solar radiation as a heat source and the low temperature background as a heat sink can be used to solve the increasingly complex problem of total thermal control of spacecraft.

Sunlight can be used with solar panels to produce electrical power for spacecraft operations. High temperature furnaces can be operated by using a solar concentrator.

The low temperature background can be used as a sink for waste heat from manufacturing applications and can also be used to operate heat engines at high efficiency.

The complete thermal control of spacecraft operations can be achieved using a balance of heat input with solar thermal collectors and heat output using thermal radiators.



## Atmospheric Pressure and Neutral Molecular Mean Free Paths

On the left the chart shows the decrease of atmospheric pressure with altitude for typical conditions. Significant variations can occur, caused by changes in solar activity. Large space chambers can be used to simulate atmospheric pressure (and other) conditions for values above about  $10^{-9}$  torr, corresponding to altitudes below approximately 1000km. On the right the chart shows that the particle mean free path (average distance traveled between collisions) increases with altitude. At low earth orbit altitudes MFP is much greater than spacecraft dimensions.

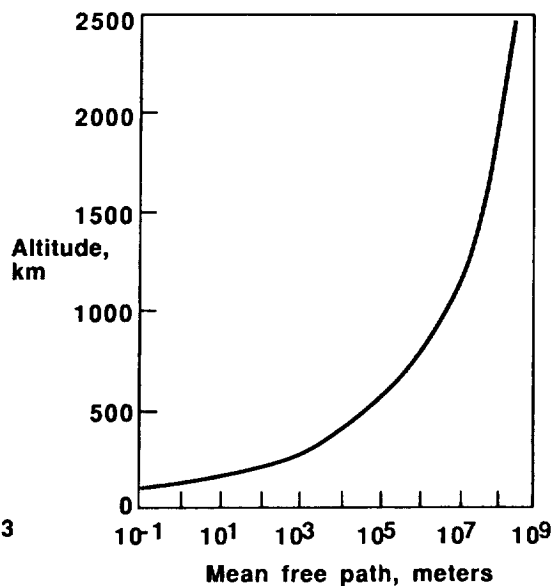
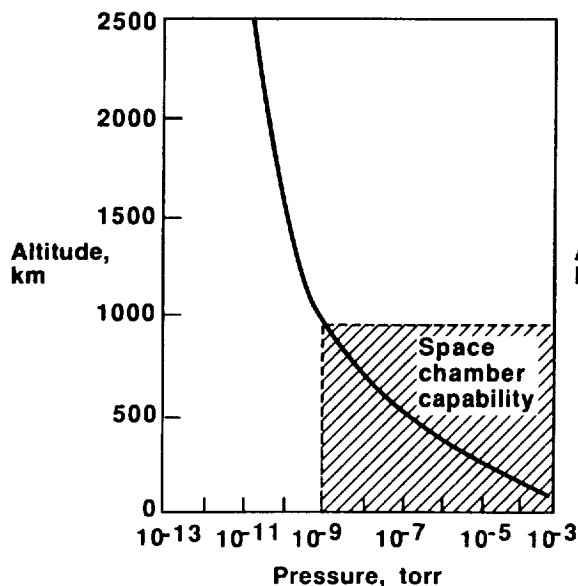
The mean free paths in the chart have been estimated for neutral particles in a typical atmosphere having an average molecular constituency. The neutral particle mean free path, which is determined by elastic (non-coulomb) collisions is of the order of 10 to 100km at low earth orbit altitudes, indicating that self scattering is negligible.

---

## Atmospheric Pressure and Neutral Molecular Mean Free Path



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## Space Ultra-Vacuum Facility Concept

At 300km the atmospheric pressure is about  $10^{-7}$ - $10^{-8}$  torr. Some processes, including the growth of pure crystalline films with molecular beams require even lower pressures. The speed of a spacecraft in orbit is greater than the speed of the residual particles in the atmosphere, which means that there is a very low pressure region in the wake of the space craft.

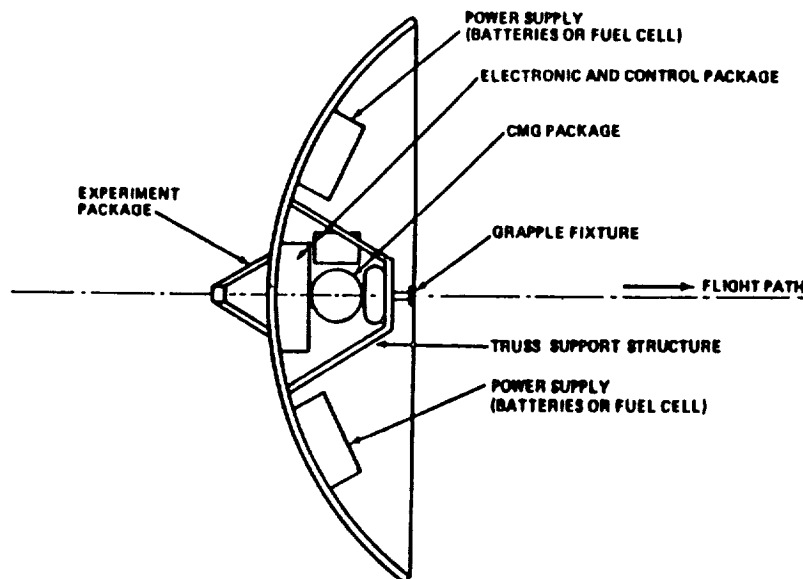
The space ultra-vacuum research facility (SURF) proposed by NASA/MSFC utilizes a large concave wake shield to produce an exceptionally low pressure in low earth orbit. Support instrumentation is located on the concave side facing the orbital direction. Experiments are conducted at the center of the convex side in the wake region of the shield. Pressures around  $10^{-14}$  torr behind the wake shield would support molecular beam epitaxy (MBE) and chemical beam epitaxy (CBE).

---

## Space Ultra-Vacuum Facility Concept



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## Wake Shield Deployment by Orbiter

The shuttle provides an opportunity for easy deployment of the wake shield ultra high vacuum system using a remote maneuvering boom. Many options for the deployment of the shield would be available on the space station.

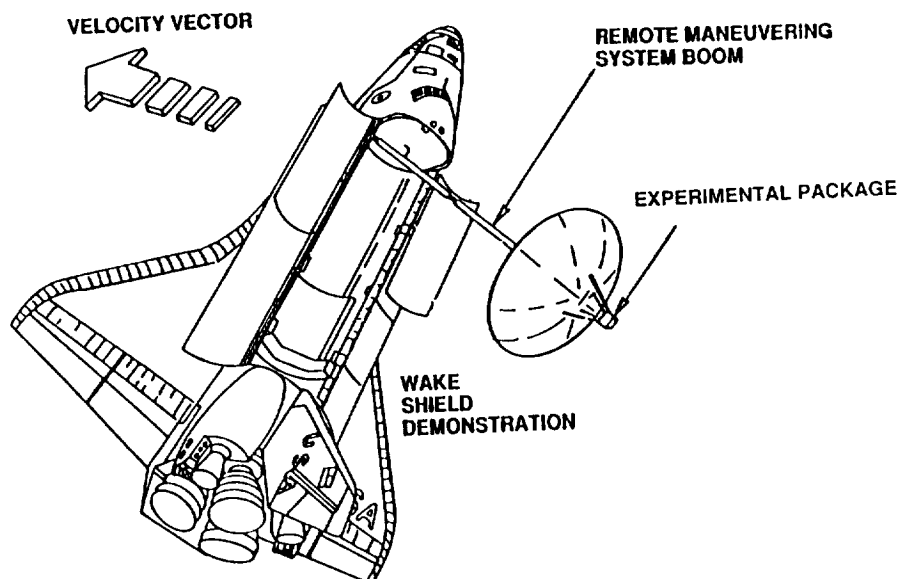
The effectiveness of the wake shield can be enhanced by orienting the shuttle so that the shield is already in the wake of the shuttle. Care must be taken so that gas leakage from the shuttle itself does not negate the effects of the shield.

---

## Wake Shield Deployment by Orbiter



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## Atmospheric Constituent Number Density

Although pressures at satellite altitudes are very low, the Earth's atmosphere does extend tenuously to these altitudes. The atmosphere is mainly atomic oxygen produced by solar-photo dissociation of molecular oxygen.

The chart shows the variation of atmospheric constituent number density with altitude calculated using the MSFA/JTO standard neutral density model. The maximum and minimum values are for maximum solar conditions at 1400 hrs and minimum solar conditions at 0400 hrs respectively. Note the anomalous behavior of Hydrogen which shows higher concentrations for the solar minimum than for the solar maximum.

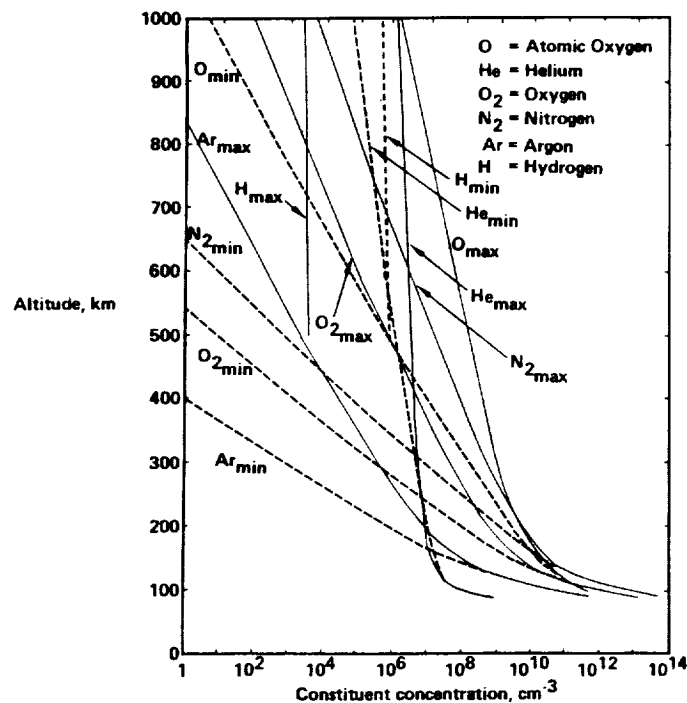
The results are based on a static diffusion model and are in agreement with experimental data from satellite drag observations.

## Atmospheric Constituent Number Density (Maximum and Minimum Solar Conditions)



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## Neutral Atmosphere Density and Temperature

The bar chart shows the range of densities for the three major neutral particle constituents of the atmosphere at an altitude of 400 km. The bulk temperature range for the neutral atmosphere is also shown.

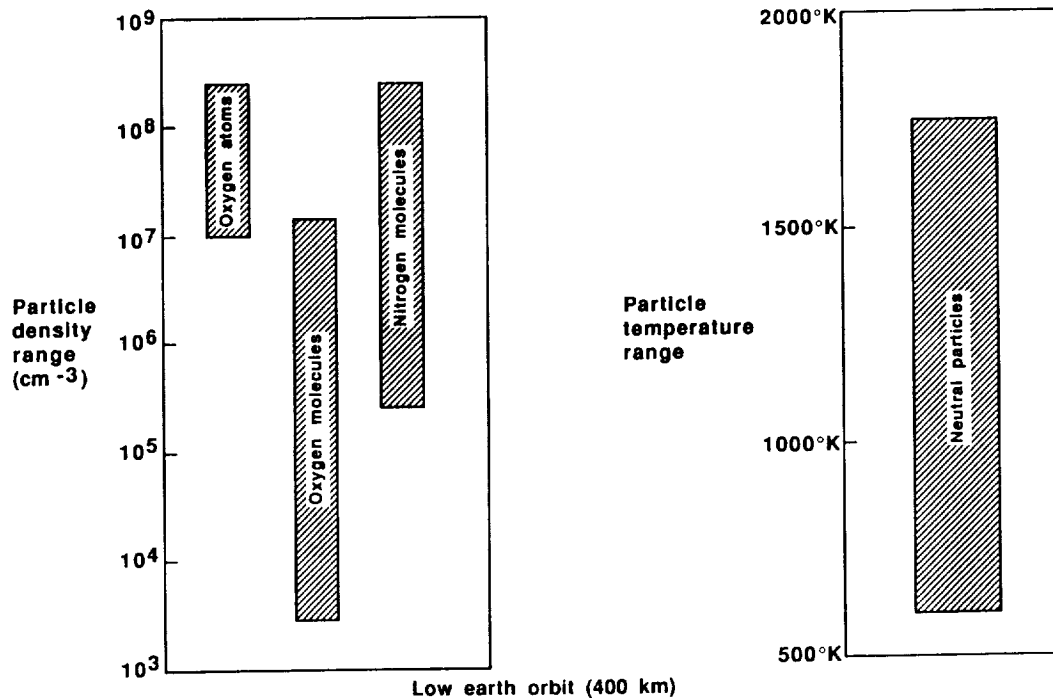
The largest part of the variation in the density and temperature is associated with the sun spot cycle and is probably due to changes in the ultraviolet light output of the sun. The remainder of the variation is due mainly to the diurnal cycle.



## Neutral Atmosphere Density and Temperature

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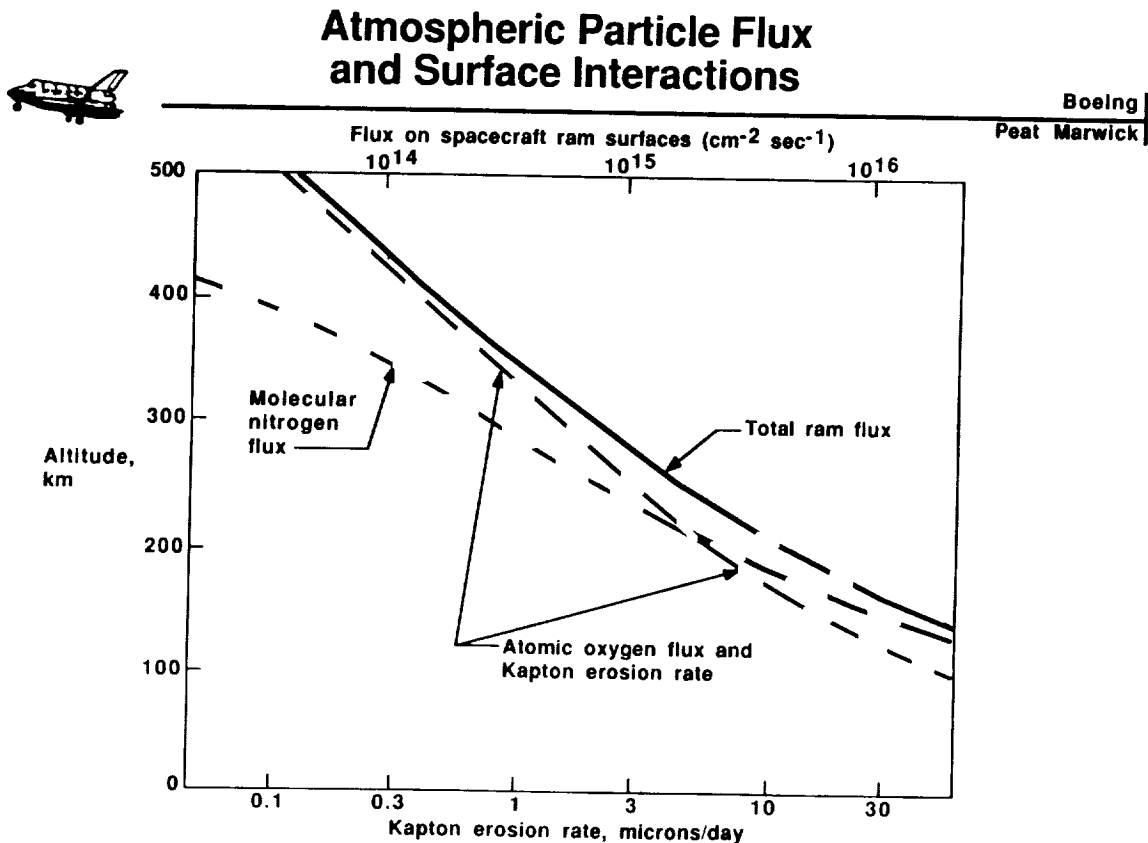
Peat Marwick



## Atmospheric Particle Flux and Surface Interactions

The orbital motion of low altitude spacecraft creates a ram wind of neutral atmospheric gases. Atomic oxygen, the primary constituent, is chemically active with many materials conventionally used on spacecraft exteriors. Degradation of plastic thermal blankets, binders in protective paints, optical coatings on lenses, and silver interconnects on solar panels has adversely affected performance. The chart shows the flux of oxygen and nitrogen and the erosion rate of Kapton as a function of altitude. Fortunately, aluminum forms an oxide that halts further interaction.

The ram flux provides a unique environment for surface treatment of materials. Atomic oxygen strikes ram surfaces with 4.8 ev of kinetic energy whereas molecular nitrogen because of its greater mass has 8.4 ev. These energies are comparable to molecular binding energies in many materials. Such conditions provide the opportunity for large-scale creation of new surface oxides under controlled conditions currently unavailable in the laboratory.



## Shuttle Glow

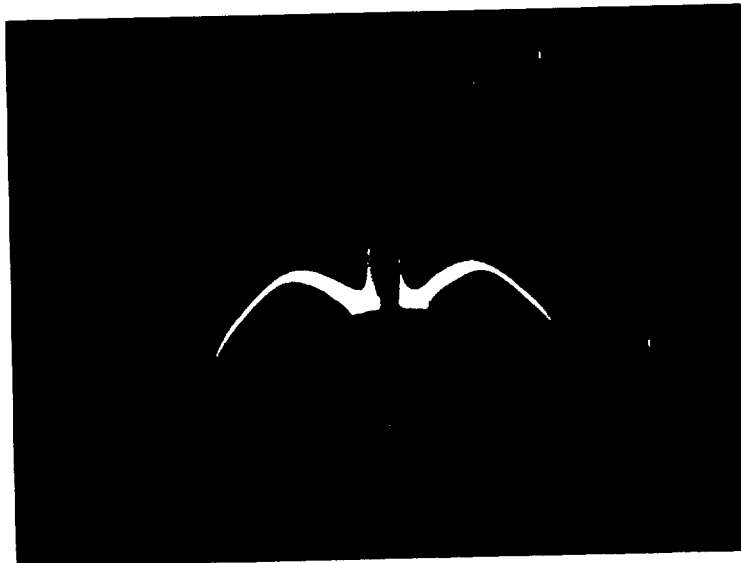
A second phenomenon associated with the residual atmosphere was observed early in Shuttle missions. A visible glow, caused by optical excitation of the residual atmosphere was observed on the leading edges of the shuttle. This photo was taken of the aft payload bay as the Shuttle traveled in the direction of its vertical stabilizer. The thin region of light (about 20 cm thick) is emitting visible and very near infrared radiation (up to 0.9 microns). The photograph is restricted to these wave lengths by the optical transmission of the lens.

---

## Shuttle Glow



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## Residual Atmosphere and Ionosphere (At Low Earth Orbit Altitudes)

The earth's atmosphere extends tenuously to Low Earth Orbit altitudes as described in the previous Section. The neutral particles are mainly atomic oxygen produced by Solar photo dissociation of molecular oxygen. Approximately one percent of the oxygen atoms are photo-ionized producing a plasma known as the ionosphere. The plasma consists mainly of positively charged oxygen ions and electrons and negative oxygen ions. Although it represents only about one percent of the gas, the plasma determines many of the properties of the gas such as the electrical conductivity and the propagation characteristics of electromagnetic waves.

The neutral and charged particle densities will be much higher on the forward facing (or RAM) surfaces and much lower on backward facing (or WAKE) surfaces.

The characteristics of the ionospheric plasma are described in the following charts.

---

## Residual Atmosphere and Ionosphere (at Low Earth Orbit Altitudes)



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- Earth's atmosphere extends to low earth orbit
- About 1 percent of atmosphere is ionized, forming a plasma

Residual neutral atmosphere	Ionosphere
99 percent	1 percent
Oxygen atoms, oxygen and nitrogen molecules	Electrons and oxygen ions
Traces of hydrogen and argon	Traces of nitrogen ions
Variations caused by solar activity	Variations caused by solar activity
Determines atmospheric drag and chemical characteristics	Determines electrical properties and electromagnetic wave propagation characteristics

## Charged Particle Densities and Temperatures

The bar chart shows the range of densities and temperatures for the major ionized species in the ionospheric plasma. As is the case with the neutral particles the ranges are due in great part to variations in solar sunspot activity and diurnal variations. It should be noted that the charged particles, unlike the neutral particles, are not in thermal equilibrium, the temperature of the electrons being considerably higher than that of the ions. This, coupled with the smaller mass of the electrons means that the velocities of the electrons are much higher than the velocity of the spacecraft, which in turn is much higher than the ion and neutral particle velocities.

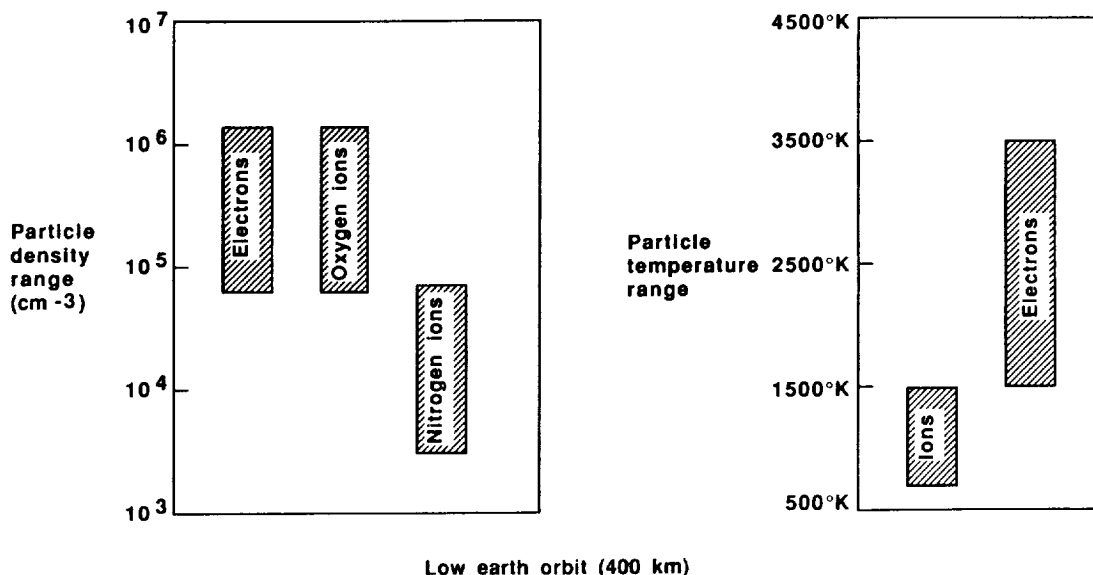
"An orbiting spacecraft is supersonic with respect to ions and stationary with respect to electrons".



## Charged Particle Densities and Temperatures

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## Natural Plasma Environment

The chart summarizes in tabular form the plasma and charged particle data which has been described in the previous few pages for typical ambient conditions in a 400 km low inclination orbit. The table shows the ion and electron number densities and temperatures and the associated thermal velocities. The thermal velocities are shown both in units of km/sec and the satellite orbital velocity,  $V_s$ . Numbers are also shown for the ion and electron fluxes per unit area of the satellite. The ion and electron gyro radii in the earth's magnetic field are also shown. The electron gyro radius is only 0.033m. indicating that the electrons are almost completely constrained to move parallel to the magnetic field lines and that the properties of the ionospheric plasma will be very anisotropic.

---

## Natural Plasma Environment



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### Typical ambient conditions (400 km - low orbit inclination)

Oxygen ion $O^+$ (90%)	Electron $e^-$ (100%)
$N_i = 2 \times 10^{11} \text{ m}^{-3}$	$N_e = 2 \times 10^{11}$
(Day: $2 \times 10^{11} - 10^{12} \text{ m}^{-3}$ , night: $7 \times 10^{10} - 10^{11} \text{ m}^{-3}$ )	
$T_i = 1000^\circ\text{K}$ (0.09 eV)	$T_e = 2500^\circ\text{K}$ (0.33 eV)
$V_i = 1.2 \text{ km S}^{-1}$ (0.15 $V_s$ )	$V_e = 300 \text{ km S}^{-1}$ (39 $V_s$ )
( $V_s$ = spacecraft orbital velocity = 7.7 $\text{kmS}^{-1}$ )	
$r_{iB}$ (gyro radius) = 4.2 m	$r_{eB} = 0.033 \text{ m}$ ( $B = 0.4\text{G}$ )
$N_i V_s$ (flux) = $1.5 \times 10^{15} \text{ m}^{-2} \text{ S}^{-1}$	$N_e V_e = 3.5 \times 10^{16} \text{ m}^{-2} \text{ S}^{-1}$



## Ionospheric Wave Propagation

The ionospheric plasma has a dramatic effect on electromagnetic wave propagation. The electron density ( $N_e$ ) in a plasma determines a natural frequency called the "plasma frequency". Numerically the value of the plasma frequency is given by  $f_p = 8980 N_e^{1/2}$  Hz. At frequencies above the plasma frequency electromagnetic waves are transmitted without significant loss, whereas at frequencies below the plasma frequency the wave is rapidly attenuated. If a wave is propagating through a plasma in which the density is increasing with distance, the wave continues to propagate until it reaches the point where its frequency is equal to the plasma frequency and it is then reflected.

The plasma frequency in the ionosphere increases with height to a maximum value and then decreases. If the frequency of the electromagnetic waves is higher than the maximum the waves penetrate the ionosphere. If not, they reflect at the appropriate height as shown in the chart, and communication "over the horizon" is possible. For communication between the surface and a satellite the signal frequency must obviously exceed the maximum plasma frequency in the ionosphere.

A plasma, particularly one with a magnetic field, such as the ionosphere, is capable of supporting a wide variety of propagation modes including acoustic and hybrid modes. The opportunity to perform propagation experiments in the ionospheric plasma is one of the attractions of the low earth orbit environment.

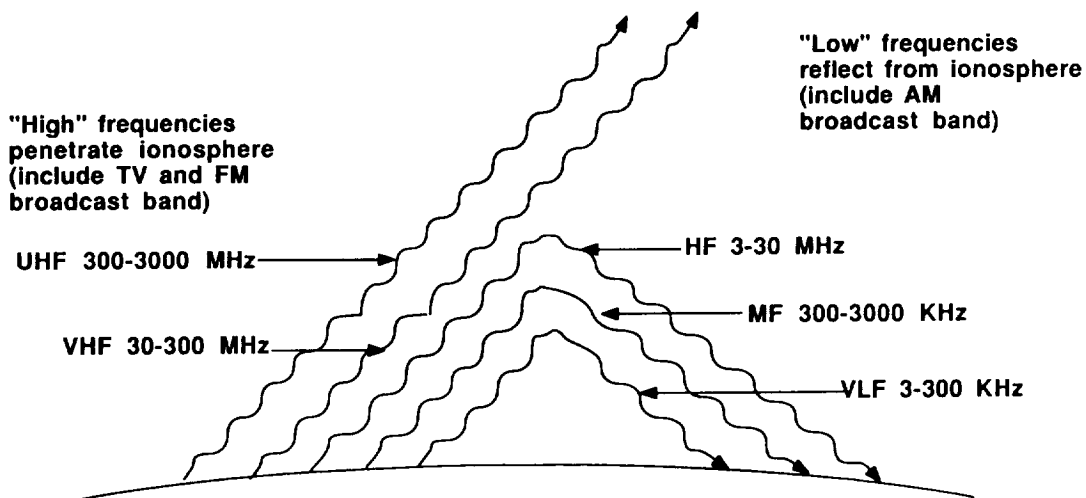


## Ionospheric Wave Propagation

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- Ionospheric plasma modifies electromagnetic wave propagation
- Waves higher than "plasma frequency" transmit
- Waves lower than "plasma frequency" reflect



## Magnetic Field

The gross features of the geomagnetic field are those of a magnetic dipole whose axis is tilted about  $10^\circ$  from the earth's geographic or spin axis. The center of the dipole is also displaced about 500 km from the geometric center of the earth. The displacement produces a region of low magnetic field strength at the earth's surface, known as the South Atlantic Anomaly.

The main magnetic field probably originates by dynamo action in the fluid motion of the molten magnetic core of the earth. Transient variations are produced chiefly by interaction between solar plasma and the geomagnetic field.

The geomagnetic field acts as a partial shield against charged particles by bending them away from the earth's surface at low latitudes and by reflecting them at high latitudes.

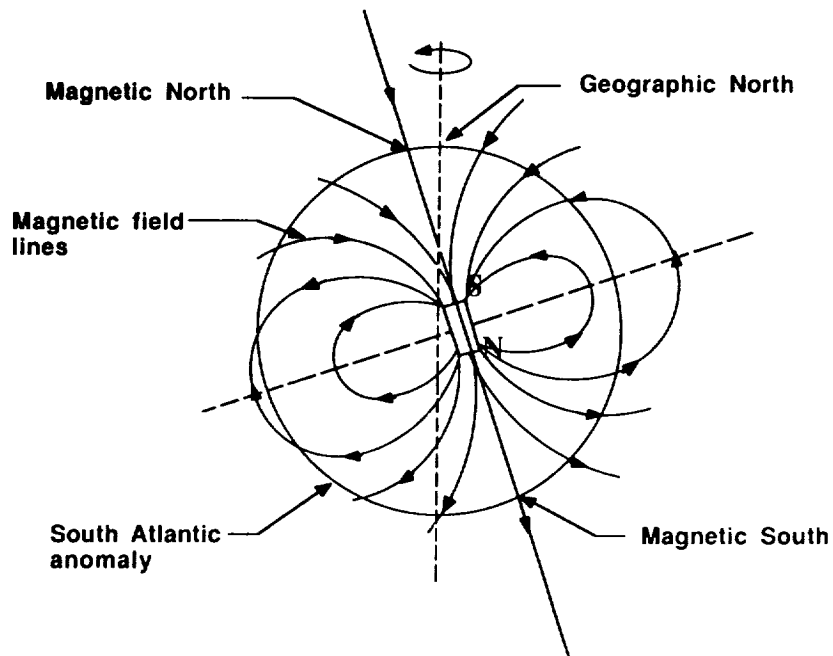
At high altitudes the magnetic field is distorted by the solar wind and merges with the interplanetary magnetic field.

---

## Magnetic Field



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## Magnetic Field Contours

The chart shows contours of constant total magnetic field strength at an altitude of 500 km. At such altitudes local surface scale variations due to iron ore deposit are not observed, the field strength decreases with altitude approximately proportionally to  $1/R$  where  $R$  is the distance from the center of the earth. At polar latitudes the magnetic field is nearly vertical, having a value of about 0.5 gauss ( $0.5 \times 10^{-4}$  Tesla). The field changes to mainly horizontal at equatorial latitudes where it has a magnitude of about 0.3 gauss except in the South Atlantic Anomaly, which can be clearly seen in the chart.

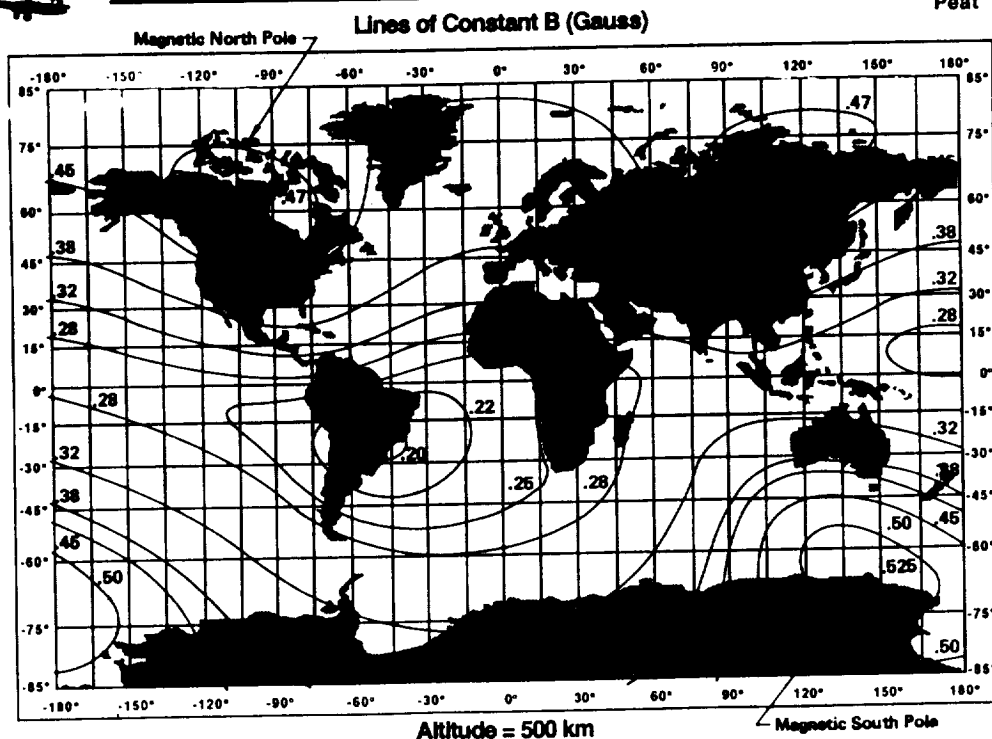
The locations of the North and South Magnetic Poles change with time. They are currently located at approximately  $75^{\circ}\text{N}$ ,  $100^{\circ}\text{W}$  and  $65^{\circ}\text{S}$ ,  $140^{\circ}\text{E}$  respectively.



## Magnetic Field Contours

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## Tether - Subsatellite Power

An electromotive force (emf) is produced in a conductor as it traverses a magnetic field. The magnitude depends on the velocity and the magnetic field strength and direction. At low earth orbital velocities it is about 0.5 volts per meter of conductor length.

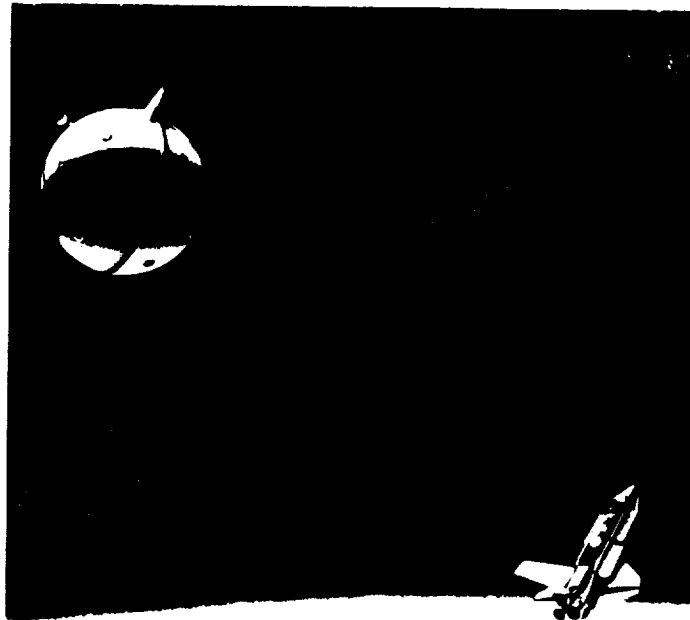
Conducting tethers between satellites can be used to generate power if one satellite collects electrons from the ionospheric plasma while the other emits them so that electric current can flow. Primary factors that limit power generation are collector area, plasma density, tether wire and load resistance, and emitter capacity. Power levels of a few kilowatts per kilometer are conceivable. An experimental tethered subsatellite for Shuttle deployment is being fabricated by Aeritalia to test the concept. The subsatellite must have elaborate guidance and control to perform the complex orbital maneuvers.

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### Tethered, Electrodynamics Mission



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# Ionizing Radiation

The near earth space environment is bombarded by high energy particles: protons, electrons, alpha particles, and other ions. Some of the particles have sufficiently high energy that they can penetrate material and in so doing they lose energy by ionizing the material. They are collectively called "Ionizing Radiation".

There are three main components of this natural radiation surrounding the earth: the trapped Van Allen belts (protons and electrons trapped by Earth's magnetic field), galactic cosmic rays (protons and high energy ions originating outside the solar system) and solar cosmic rays (protons and alpha particles emitted by intense solar flares, 30-50 such events per 11-year cycle). The different components of the radiation are discussed in the next few charts.

The high energy, highly charged ions of the GCR can be simulated at only a few facilities worldwide, but with significant limitations (low atomic number, energy <100 Mev/nucleon; the BEVALAC at Berkeley California has fewest limitations).

---

## Ionizing Radiation



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High energy particles (radiation) penetrate the near Earth space environment

- Main sources of high-energy radiation
  - Trapped radiation belts
  - Galactic Cosmic Rays (GCR)
  - Solar Cosmic Rays (SCR)
- Types of radiation
  - Protons (trapped belt, GCR, SCR)
  - High energy ions (GCR)
  - Electrons (trapped belt)
- Ability to simulate space radiation
  - High energy protons — large cyclotrons
  - High energy ions — Berkeley BEVALAC
  - Electrons — linear accelerators

## Trapped (Van Allen) Radiation Belts

High-energy protons and electrons are trapped by the geomagnetic field in Van Allen radiation belts. In the radiation belts the charged particles follow spiral orbits along magnetic field lines and are reflected by increasing field strength near earth. The chart shows crescent-shaped flux contours which encircle globe out to several earth radii.

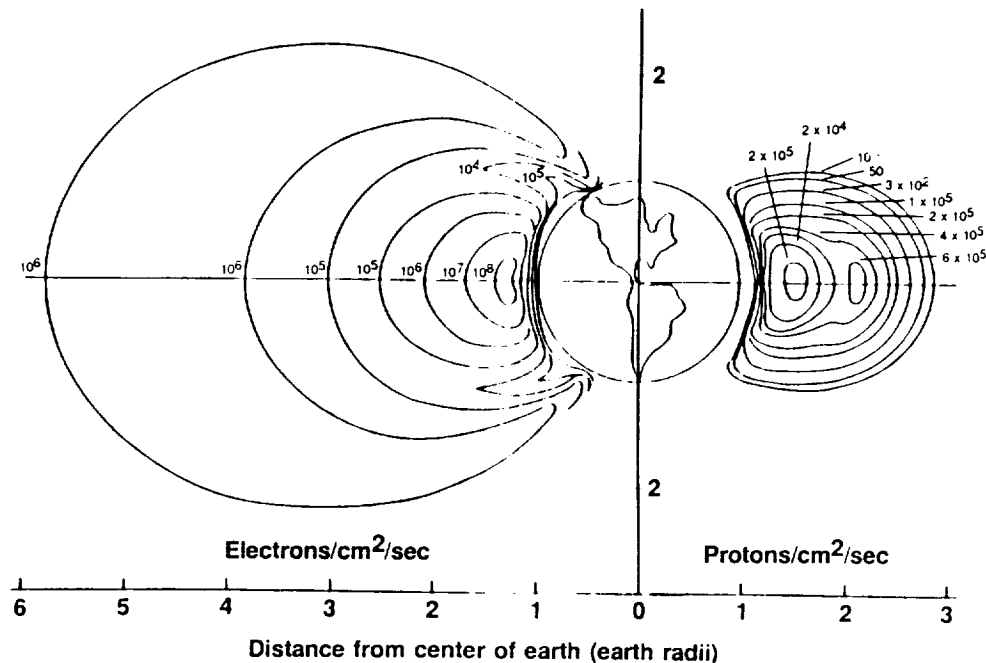
The discovery of the trapped radiation belts in 1958 was a key milestone in space research. The electrons collide with atoms in the outer skin of the spacecraft creating penetrating x-rays and gamma rays that cause tissue damage. The energetic protons can penetrate several grams of material (1-2cm of aluminum is required to stop them) causing ionization of atoms as they terminate in nuclear collisions. Most manned spacecraft missions are restricted to altitudes below 500km to avoid prolonged exposure to this damaging radiation. The lower edge of the belts is controlled by the geomagnetic field and scattering by the upper atmosphere.

## Trapped (Van Allen) Radiation Belts



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## Trapped Belt Electron Flux

Electrons trapped by the earth's magnetic field are part of both the inner belt (500-12,000 km) and the outer belt (18,000-36,000 km). The electron flux peaks at altitudes ranging from approximately 2000-5000 km in the inner belt and at approximately 20,000 km in the outer belt, depending on the electron energy. The electron flux is shown at an altitude of 500 km in the chart.

Because of a sharp decrease in the earth's magnetic field in the area of the South Atlantic, the inner belt electron flux has a high value area known as the South Atlantic Anomaly.

At high latitudes the geomagnetic field lines "bunch in" toward the magnetic poles, allowing energetic electrons of the outer belt to follow the field lines down to low altitudes.

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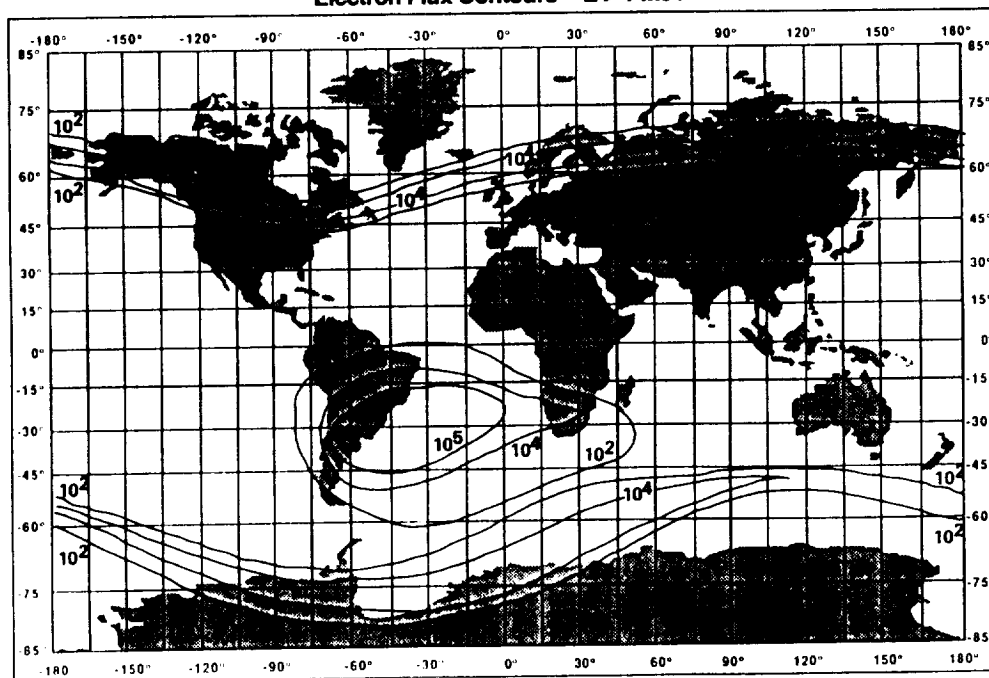
## Trapped Belt Electron Flux



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Electron Flux Contours –  $E > 1$  MeV



Altitude = 500 km

## Trapped Belt Proton Flux

Protons trapped by the geomagnetic field are part of the inner trapped belt which extends from about 500-12,000 km and peaks at approximately 2000-5000 km, depending on the proton energy.

As for the electrons the proton flux peaks over the South Atlantic Anomaly. At Shuttle and Space Station altitudes, i.e. an altitude of 500 km, the only appreciable proton flux is encountered in the South Atlantic Anomaly as shown in the chart.

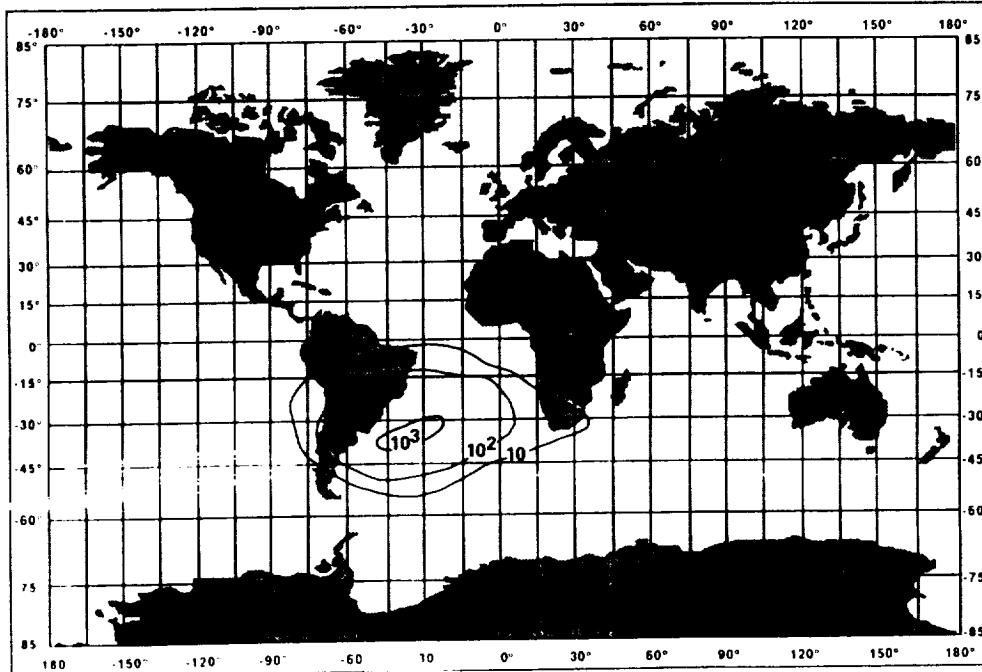


## Trapped Belt Proton Flux

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Proton Flux Contours –  $E > 50 \text{ MeV}$



Altitude = 500 km



## Aurora

The Aurora Borealis and Australis are visible manifestations of the intense activity in the geomagnetic field surrounding Earth. Observed and studied since ancient times, its true explanation awaited the discovery of the trapped radiation belts. Disturbances in the geomagnetic field scatter trapped electrons and protons into the upper atmosphere at high latitudes where they excite the oxygen and nitrogen atoms and molecules. The variety of auroral color is due to mixing of line emissions from the discrete excited states of the atmospheric gases.

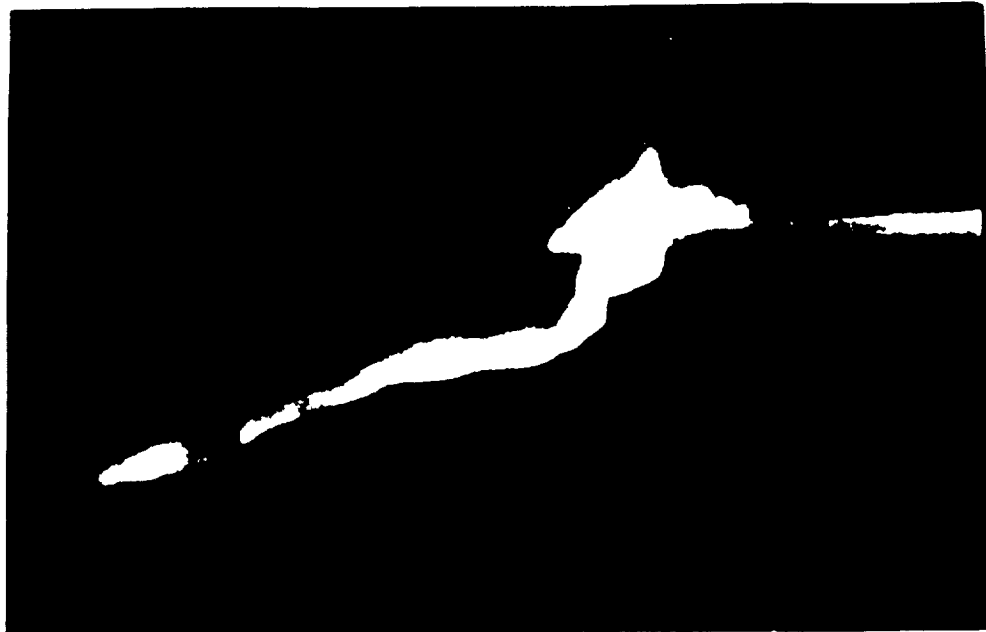
The spatial variability of aurora is demonstrated in this satellite photo of the auroral band extending thousands of miles across the northern hemisphere. Interaction of solar flare plasma with the geomagnetic cavity causes periods of enhanced activity when aurora becomes visible in the continental U.S.

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### Satellite Observations of Aurora



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## Enhanced Growth of Microorganisms in Space

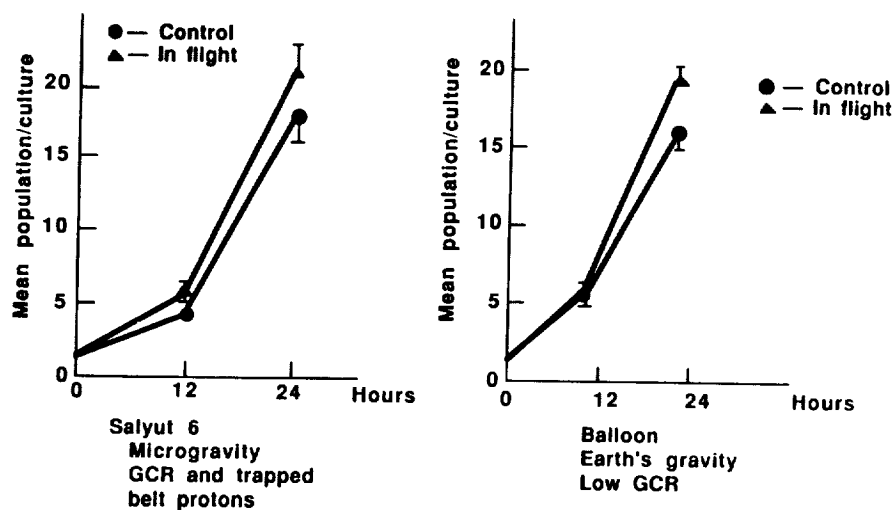
The effect of radiation on biological systems has generally been harmful. This includes the induction of developmental anomalies in animals, cancer in humans, mutations in plants and retardation of all development and colony formation in microorganisms. However, experiments with *paramecium tetraurelia*, a simple, unicellular organism, have shown enhanced colony growth due to the combined effect of space radiation and microgravity. This leads to the prospect of enhanced growth in more useful microorganisms, e.g., euglena, bacteria spores, genetically-engineered biomolecules. Additional radiobiology experiments in space may therefore be of interest to pharmaceutical firms.



### Enhanced Growth of Microorganisms in Space Radiation

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Growth rate of *Paramecia* cultivated and fixed in a balloon flight  
or aboard the orbital station Salyut 6

## Radiation Hormesis

At low doses, radiation has been shown to have a hormetic, i.e. stimulating, effect on the growth of both plant and animal organisms. For plants in particular, the hormesis response is a common phenomenon that is not restricted to either plant species or radiation type. The chart shows the change in growth to barley and wheat as a function of radiation dose, when exposed to four different radiation sources.

For space-food growing experiments relying on the growth of many generations of plant cycles, this hormetic effect may be important for increasing the food yield. The hormetic radiation effect could be delivered by using either the natural space radiation or on-board radiation sources.

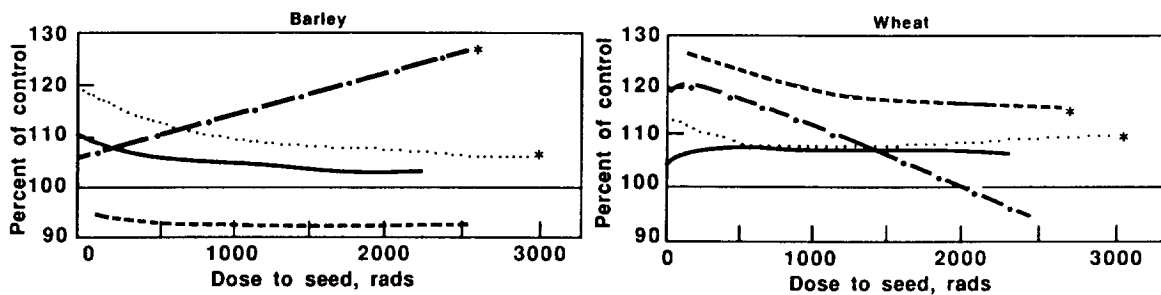


## Radiation Hormesis

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Peat Marwick

### Radiation source

- X-ray
- - - Iridium-192
- ... Cesium-137
- · - Cobalt-60



Estimates of relative dry weight at 11 d of barley and wheat plants grown in the growth chamber from seed irradiated with four different sources

## Cosmic Ray Induced Single Event Upset

A Single Event Upset (SEU) is an anomolous change in a semiconductor logic device. SEUs in modern electronics in space are caused by cosmic ray particles or trapped protons. As the particles pass through material they lose energy by ionizing the material and producing additional pairs of charged particles. If the charged particles are near the junction of a semiconductor device in a memory cell they can produce a current pulse large enough to cause a change in state of the memory cell. No permanent damage is done, but the data store in the cell is now in error. Such errors induced in existing spacecraft are causing significant reductions in system lifetime and reliability.

Development of large scale integrated circuits, coupled with the decreasing size of individual circuit elements, has made space borne electronics increasingly susceptible to SEU because the current required to change the state of the memory cell has become smaller and smaller. Techniques are evolving to reduce the system error rates to a tolerable level.

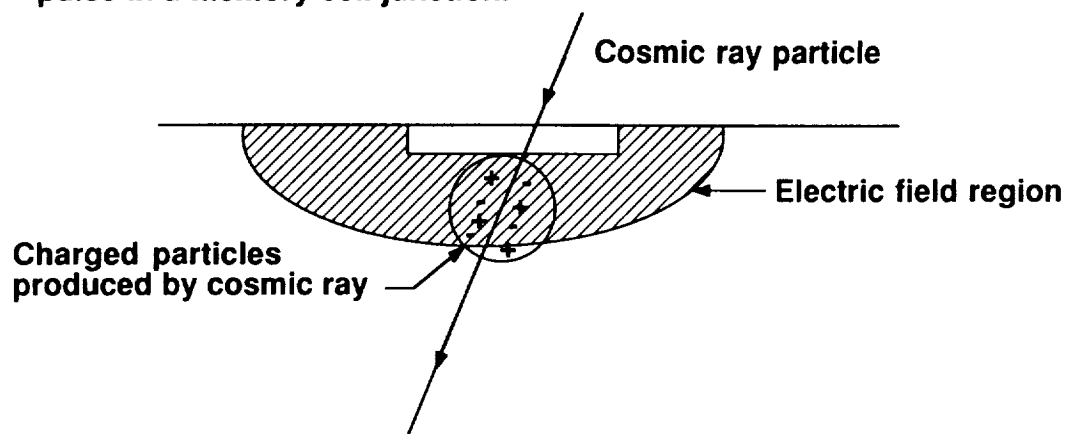


### Cosmic Ray Induced Single Event Upset

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Peat Marwick

- Single Event Upset (SEU) is caused by a cosmic ray induced current pulse in a memory cell junction.



- Charged particles move in the electric field of the junction.
- The current produced causes the memory cell to change state.
- Erroneous information is stored in memory

## Meteoroid Environment - Terrestrial-Space Influx of Meteoroids

Most meteoroids originate from comets or asteroids outside earth orbit and hence have high velocities. Meteoroids from comets are icy. Meteoroids from asteroids are stony and may contain silicon, iron, magnesium, and other minerals. Since the major source of meteoroids is comets, the average density is around  $0.5\text{g/cm}^3$ .

Meteoroid Environment does not change significantly from year to year, although the hourly influx may vary as the Earth moves through the meteoroid streams left in the orbital paths of comets or fragmented asteroids. The total mass influx to the Earth is estimated to be  $10^{10}$  grams per year.

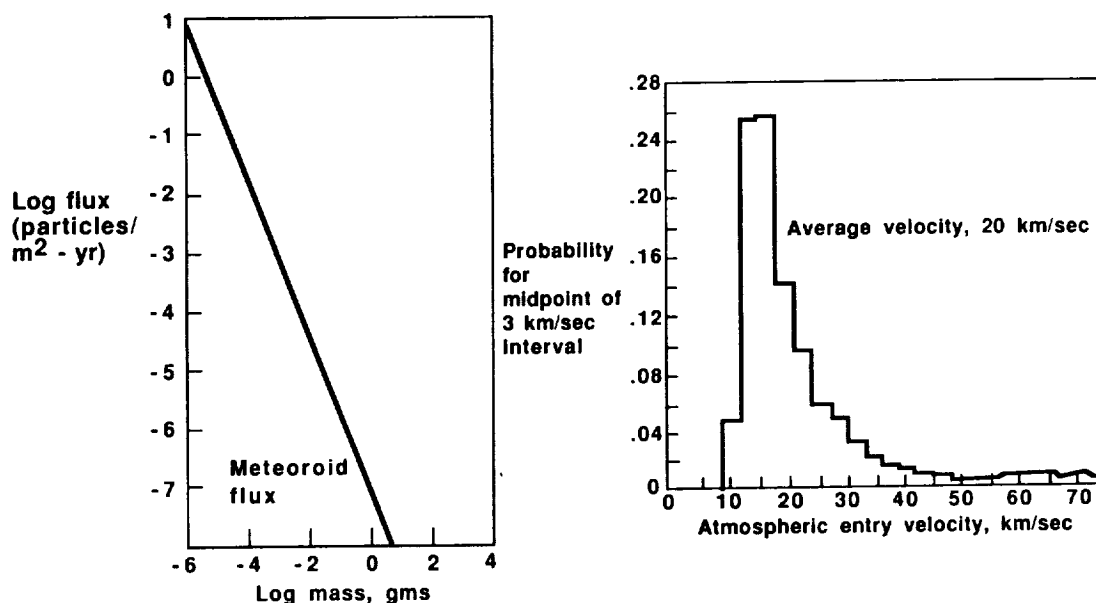
Meteoroid influx is measured with: impact detectors on satellites, visual observation of meteor trails in the atmosphere, zodiacal lights, lunar crater accounts, and by retrieving meteoroid material from the sea floor and from the polar icecaps. The meteoroid flux line results from many sources of data and shows that meteoroid size is inversely related to frequency. The flux for meteoroids less than  $10^{-12}$  grams is uncertain.



### Meteoroid Environment — Terrestrial-Space Influx of Meteoroids

Average Mass Density =  $0.5\text{ g/cm}^3$

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Source: NASA SP 8013 Meteoroid Environment Model — 1969

## Orbital Debris Environment Altitude and Latitude Variation

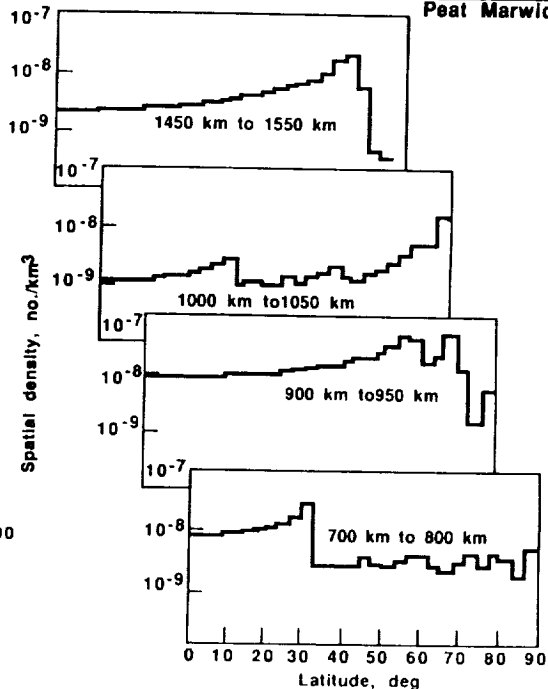
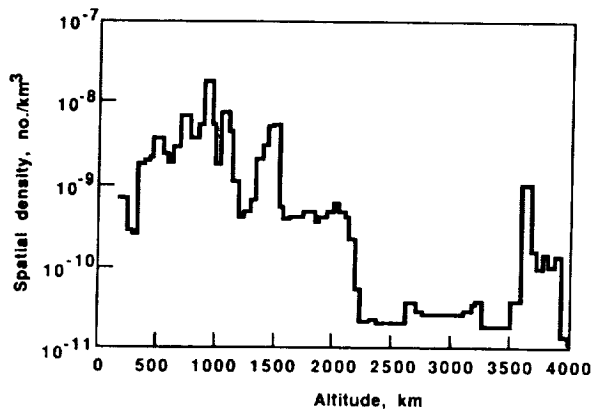
Debris is created during orbital activity. The sources of orbital debris include fragments from satellite destruction (collisions and explosions) and objects released during routine orbital operations. The debris environment shown in the charts is measured using ground based radar. Currently approximately 5,000 objects are tracked and including those below the radar threshold it is estimated that there are from 10,000 to 15,000 particles in orbit. The chart shows the variation of debris density (particles per unit volume) as a function of altitude and latitude. The variations are due to orbital decay and the preferential use of some altitudes and orbital inclinations.



### Orbital Debris Environment — Altitude and Latitude Variation

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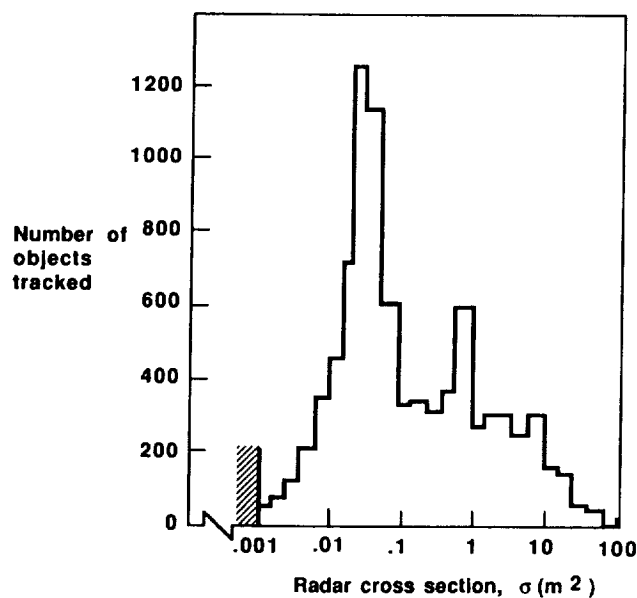
## Radar Tracked Objects in Low Earth Orbit

Debris size distribution is obtained from radar cross section measurements. Radar sensitivity for small objects is low, therefore the number of small objects in orbit is greater than detected by radar. Flux for these small objects is estimated from extrapolations of known satellite explosions and is assumed similar to the meteoroid flux.



## Radar Tracked Objects in Low Earth Orbit

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## Particle Velocity Distribution in Low Earth Orbit

The velocity of collisions between spacecraft and orbital debris depends on the spacecraft orbit. Most debris impacts occur between 8 km/s and 16 km/s. The velocity distributions are shown in the chart and are derived from the orbital mechanics of the spacecraft and known debris orbits. The majority of expected debris impacts will occur above 8 km/s, which is the limit of current testing capability.

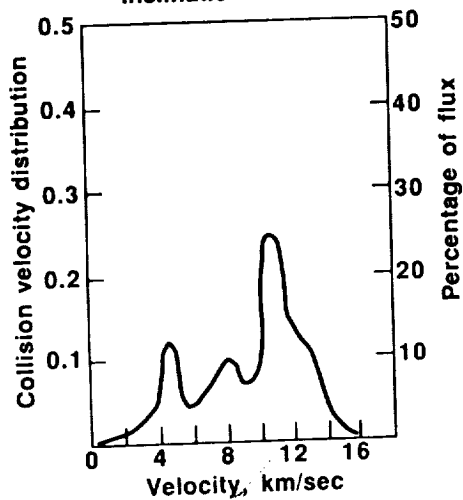
## Particle Velocity Distribution in Low Earth Orbit



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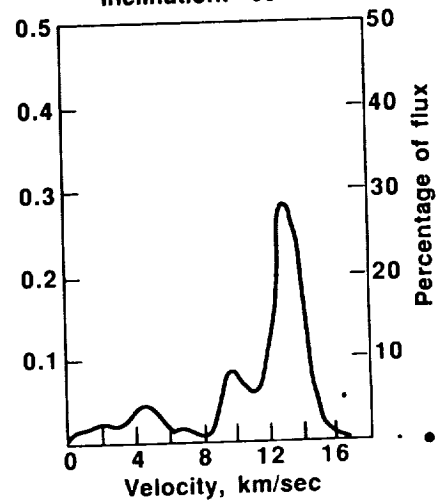
### Spacecraft orbit

Altitude: 500 km  
Inclination: 30°



### Spacecraft orbit

Altitude: 500 km  
Inclination: 60°





## Orbital Debris and Meteoroid Flux and Growth Predictions

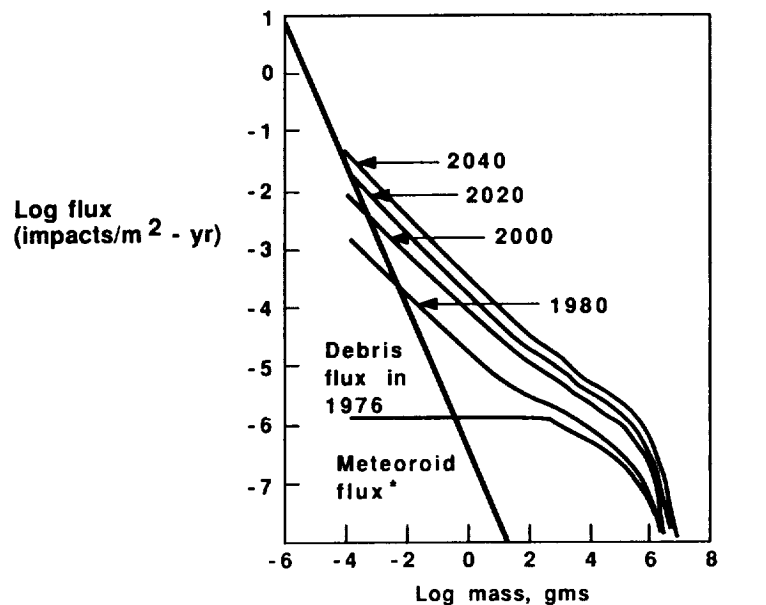
The chart shows the debris and meteoroid flux represented as the expected number of impacts per unit area per unit time on a spacecraft in orbit at 800 km altitude. As the spacecraft size and mission length increases, more impacts of larger particles will be expected. The debris flux is more important than the meteoroid flux because debris particles large enough to penetrate spacecraft are more numerous. The debris flux is not expected to change significantly with orbit inclination. The meteoroid flux has been corrected for earth shielding and gravity focusing.

In the middle 1970's, during the use of SKYLAB, the orbital debris flux was much less than present. Continued growth is expected in debris flux. The chart shows the predicted growth in debris flux for an altitude of 800 km. Similar growth rates are expected at other altitudes. The debris flux increases with time because debris continues to be released during orbital activity and because existing debris fragments collide with each other producing more particles.

## Orbital Debris and Meteoroid Flux and Growth Predictions



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Average equilibrium debris flux at 800 km

\* Corrected for Low Earth Orbit (Earth shielding and gravity focusing)

## Debris/Meteoroid Hazard and Dual Plate Shielding System

Both natural (meteoroid) and manmade (debris) particles pose a threat to orbiting spacecraft.

"The possibility that large antimissile spacecraft could be disabled by the billions of particles of manmade debris orbiting the Earth is an area of increasing concern to the Strategic Defense Initiative Organization. This is so because a particle smaller than a grain of sand flying at Mach 25 could destroy an unprotected SDI vehicle. It also could severely damage the U.S./international space station planned for the 1990s. The Air Force is focusing on characterization of the debris hazard and on protection technology. NASA has told outside advisors a safety problem clearly exists."

Aviation Week and Space Technology March 16, 1987

The chart shows the performance of a proposed dual plate shielding system under hypervelocity impact. The most weight efficient shield against meteoroids incorporates at least two separated plates. The first plate is designed to inhibit penetrations in the second by breaking up the particle and spreading out the fragments. The penetration threshold represents the division between penetrating and non-penetrating particles, and is defined with test data and theoretical analysis. Large particles are more penetrating than small particles. Slope changes in the penetration threshold reflect the velocity dependence of hypervelocity impact mechanics; low velocity particles do not break up as much upon first plate impact leaving a more lethal fragment.

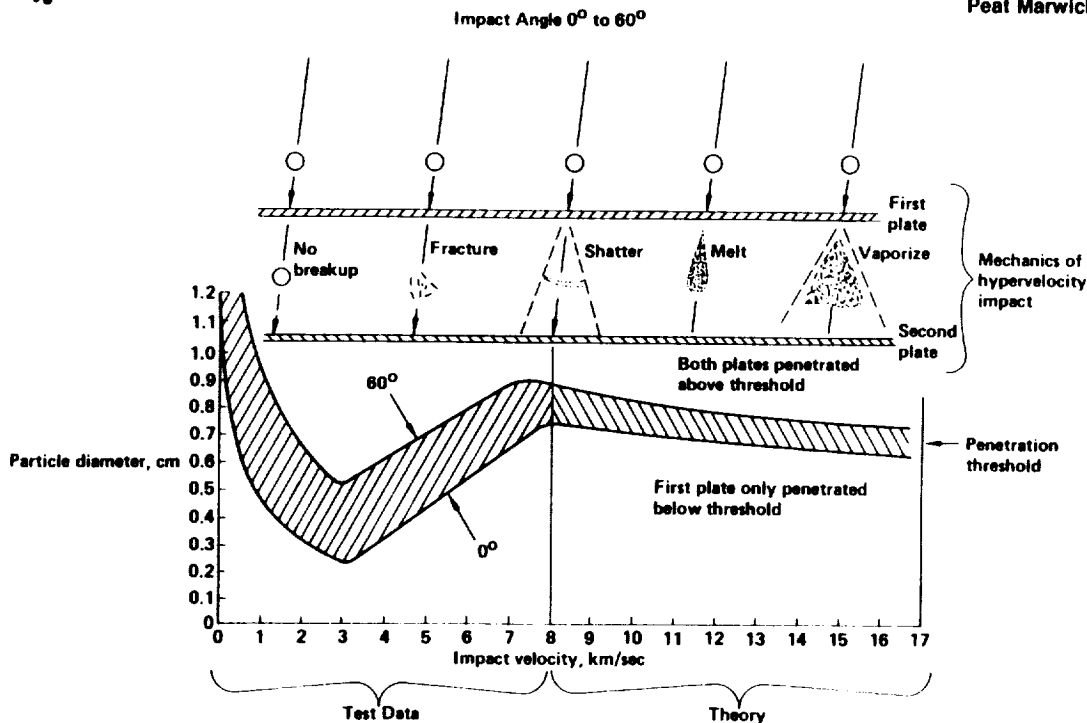
The capability of current testing systems limit the test data to below 8 km/s, therefore the penetration threshold above 8 km/s relies on theory. The majority of orbital debris impacts are expected at velocities above current test capability. The average meteoroid impact velocity is 20 km/s which will vaporize the particle.

## Debris/Meteoroid Hazard and Dual Plate Shielding System



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Peat Marwick



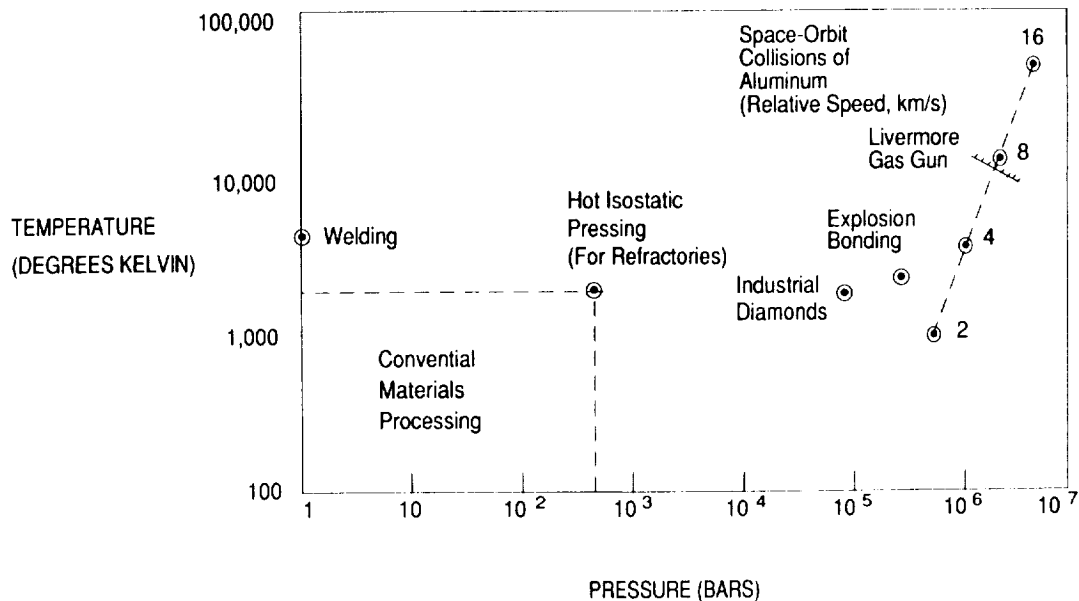
## Ultra High-Speed Collisions

Orbital collisions provide a unique test-bed for ultra-high kinetic energy processes. Satellites in low earth orbit travel at 8 km/sec along their trajectories. By counter-orbiting objects (e.g., in polar orbits), a relative collision speed of 16 km/sec can be attained. Such a collision generates exceptionally high pressures and temperatures, well beyond terrestrial processing capability. The experimental light gas gun at Livermore can achieve comparable operating conditions for very minute projectiles. The most energetic high strain rate materials processing is explosive bonding of metals and explosive industrial diamond manufacturing. Possible future applications include processing of refractory or ultra-hard compounds.

## Ultra High-Speed Collisions



Boeing  
Peat Marwick



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## INTERNATIONAL ACTIVITIES

Dr. Hans E.W. Hoffmann provided the Workshop with a briefing on international space commercial activities and INTOSPACE, GmbH. In his remarks, Dr. Hoffmann discussed the European Space Agency (ESA) and the evolution of the ESA program from purely scientific to application oriented. Other key points and topics were:

- The early space successes led to commercialization plans but were predicted too early. Only with telecommunications has commercialization been achieved.
- Steps to commercialize space: Utilization by non-aero companies, industrialization, commercialization.
- Government support is essential to take the first step.
- TEXUS system was developed to provide simple, early, and cheap flight opportunities to initiate the utilization process.
- Discussion of Arianespace, EUTELSAT, SPOT, and INTOSPACE creations.
- Discussion of INTOSPACE's efforts and challenges in promoting the utilization of the SPACE LAB and Space Station.
- Discussion of user industry's impressions of space and their criteria for involvement.
- The current situation is a transition between government sponsored programs to industrial user sponsored programs.



## STEPS TO COMMERCIALIZATION

### UTILIZATION

BY NON-AEROSPACE INDUSTRY

### INDUSTRIALIZATION

BY INDUSTRIAL RESPONSIBILITY AND RISK SHARING

### COMMERCIALIZATION

BY RETURN OF INVESTMENT

**ASN**

**ARBEITSGEMEINSCHAFT SPACELAB NUTZUNG**  
- WORKING ASSOCIATION SPACELAB UTILIZATION -  
- FOUNDED IN 1975 -

**ASN**  
WORKING  
TEAM

↑↓  
**TWO REPRESENTATIVES**  
OF EACH  
ASN - MEMBER

#### CHARTER:

- SUPPORTING THE BNFT IN DESIGNING A LONGTERM BASIC SPACELAB UTILIZATION PROGRAM THE ASN WILL PRIMARILY PERFORM
  - COOPERATIVE PLANNING OF A SPACELAB UTILIZATION PROGRAM (CONTENT AND BUDGET)
  - POTENTIAL UTILIZATION INVESTIGATIONS COUPLED WITH MARKET RESEARCH
  - RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT GOALS
  - SCIENTIFIC AND ORGANISATIONAL SUPPORT TO THE USER COMMUNITY
  - CONTINUOUS INFORMATION EXCHANGE BETWEEN MEMBERS WITH REGARD TO SPACELAB UTILIZATION ACTIVITIES

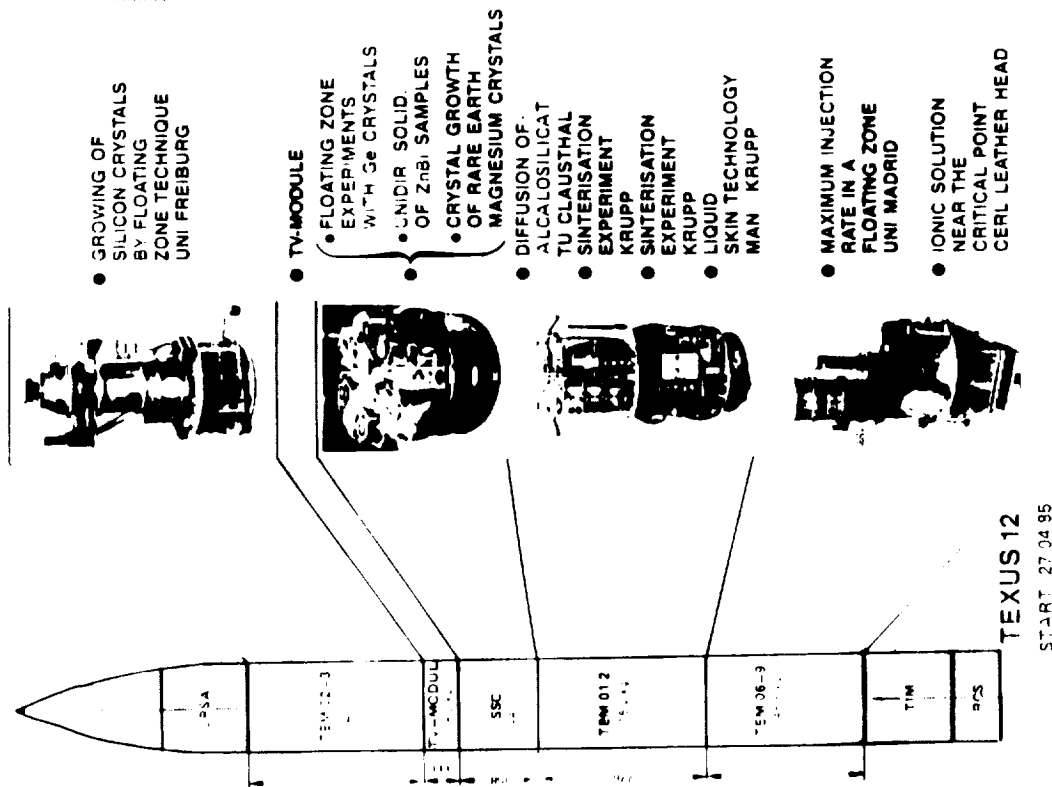
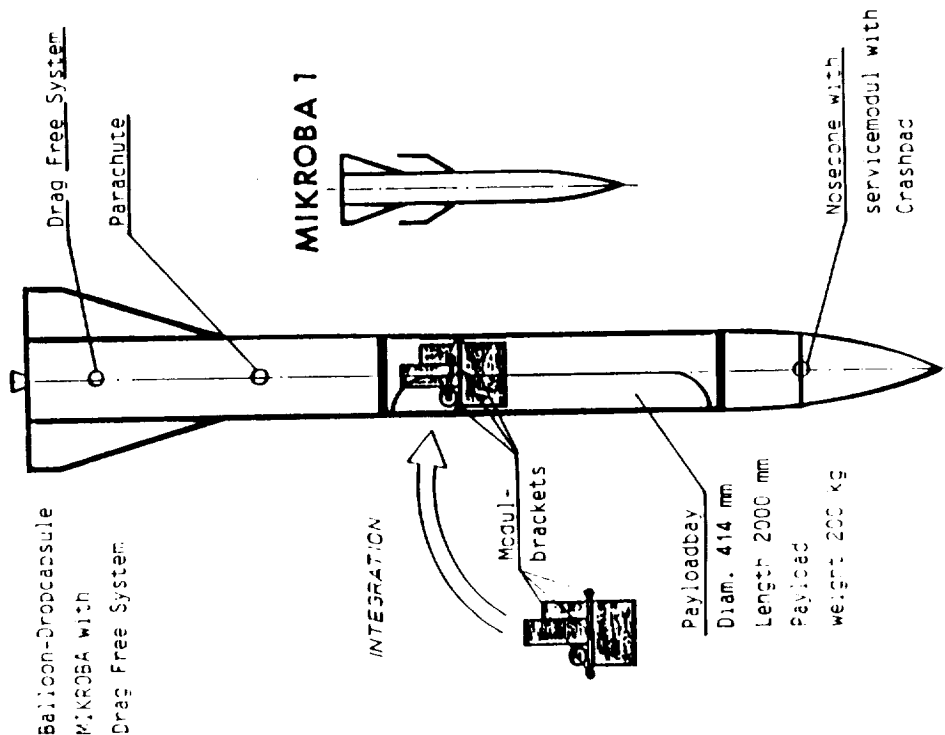
#### MAIN ACTIVITIES

- PROMOTION AND DEVELOPMENT OF SPACE SHUTTLE/SPACELAB UTILIZATION
  - ACQUISITION OF POTENTIAL USERS
  - SUPPORT OF USER COMMUNITY IN DEVELOPING SPACE EXPERIMENTATION
- JOINT DISCUSSIONS ASN/BNFT WITH BNFT
  - SPACE SHUTTLE/SPACELAB UTILIZATION PLANNING
  - COMMERCIALIZATION POTENTIAL
- JOINT PR ACTIVITIES
  - EXHIBITIONS
  - PERIODICALS (USER INFORMATION)
  - MARKETING

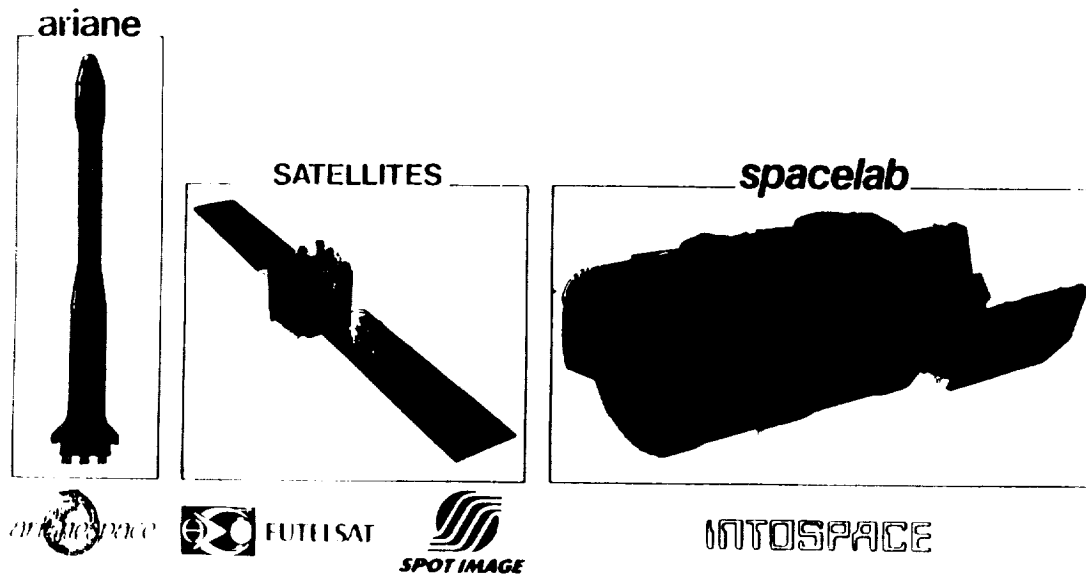


# BALLOON-DROPCAPSULE MIKROBA





## MIKROBA 2



## EUROPEAN VENTURES



## MARKET SEGMENTS FOR THE UTILIZATION OF SPACE

- SATELLITES, TELECOMMUNICATIONS  **COMSAT**
- LAUNCH AND TRANSPORTATION SERVICES 
- INTEGRATION AND IN-ORBIT SERVICES **ASTROTECH**
- EARTH OBSERVATION  / 
- UTILIZATION OF MICROGRAVITY ( $\mu g$ ) **INTOSPACE**



#### PURPOSE OF THE COMPANY

---

AN INTERNATIONAL COMPANY TO PROMOTE, INITIATE  
AND SUPPORT MICROGRAVITY SPACE ACTIVITIES SUCH AS  
RESEARCH, DEVELOPMENT AND PRODUCTION IN SPACE AS WELL AS TO  
PROVIDE ASSISTANCE AND CONSULTANCY FOR SUCH  
ACTIVITIES

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INTOSPACE  
GmbH

THE USER INDUSTRY IS THE NON-AEROSPACE INDUSTRY.

HOW ARE THEY INFORMED ABOUT THE OPPORTUNITIES OF SPACE  
UTILIZATION?

GENERALLY BY THE MEDIA.

IN EUROPE THERE<sup>R</sup> EXISTS NO SYSTEM FOR AN IN-DEPTH INFORMA-  
TION BY THOSE WHO HAVE THE KNOW-HOW FOR THOSE WHO NEED  
TO KNOW.

THIS IS THE BACKGROUND OF THE INTOSPACE FOUNDATION.

THE GENERAL IMPRESSION OF THE NON-AEROSPACE INDUSTRY ABOUT SPACE IS:

- SPACE IS A VERY RISKY BUSINESS
- SPACE IS VERY EXPENSIVE
- SPACE FLIGHT PREPARATION TAKES A VERY LONG TIME
- SPACE IS A GOVERNMENT BUSINESS, THE USERS ARE THE SCIENTISTS.
- TO ACQUIRE TECHNOLOGY YOU DO NOT NEED SPACE.

THE FIRST INDUSTRIAL USER CRITERION IS:  
CONFIDENTIALITY

THE SECOND INDUSTRIAL USER CRITERION IS:  
DETAILED INFORMATION OF WHAT HAS BEEN DONE BEFORE AND  
WHAT SEEMS TO BE POSSIBLE

THE THIRD INDUSTRIAL USER CRITERION IS:  
CONTACT WITH REKNOWN SCIENTISTS IN THEIR RESPECTIVE  
FIELD OF ACTIVITY

THE FOURTH INDUSTRIAL USER CRITERION IS:  
CONTACT WITH COMPLEMENTARY INDUSTRIAL PARTNERS  
IRRESPECTIVE OF THEIR NATIONALITY

THE FIFTH INDUSTRIAL USER CRITERION IS:  
FINANCE

**CHINA → GREAT WALL INDUSTRY CORP.**

**USSR → GLAVCOSMOS**

**JAPAN → SPACE TECHNOLOGY CORPORATION**  
**OTHERS – CREATED BY MITI**

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## **COMMERCIALIZATION CRITERIA**

- **FULL SUPPORT OF GOVERNMENTAL AGENCIES**
- **CLOSE SCIENTIFIC/INDUSTRIAL COOPERATION**
- **INTERNATIONAL COOPERATION**

## SPACE STATION TECHNICAL OVERVIEW

Dr. John-David F. Bartoe, Chief Scientist, Office of Space Station, provided the Workshop a briefing on the technical aspects of the Space Station. The briefing covered the planned capabilities, resources available to the users, and the interfaces to the station. Dr. Bartoe described the current Space Station configuration and discussed the following items in detail:

- Orbit and Attitude Parameters
- Microgravity Environment
- Mechanical Interface - Pressurized Volume
- Mechanical Interface - External Attachment Points
- Power System
- Thermal Control System
- Data Management System
- High Rate Data and Video
- Crew Resource
- Payload Transportation
- Polar Platform



## SPACE STATION

- Space Station Technical Overview
- OSSA Space Station Initiative
- Rapid Response Research

**Dr. JOHN DAVID F. BARTOE**  
Chief Scientist  
Office of Space Station  
November 4, 1987



## SPACE STATION TECHNICAL OVERVIEW PHASE 1 CONFIGURATION

---

- Orbit and Attitude Parameters
- Microgravity Environment
- Mechanical Interface - Pressurized Volume
- Mechanical Interface - External Attachment Points
- Power System
- Thermal Control System
- Data Management System
- High Rate Data and Video
- Crew Resource
- Payload Transportation
- Polar Platform

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10/29/87



## ORBIT AND ATTITUDE PARAMETERS (AT PHASE 1 COMPLETION)

---

- Altitude: 180-270nm (290-430km)
  - Varies with solar cycle
  - Flies at lowest altitude having atmospheric drag  $< .3 \times 10^{-6}G$
- Inclination: 28.5 degrees
- Reboost period: Approximately 90 days
- Attitude
  - Orientation: Torque equilibrium attitude (Approximately LVLH)
  - Deadband: 5 degrees peak-to-peak
  - Rate:  $< .02$  degrees per second
  - Knowledge: .01 degrees, 3 sigma

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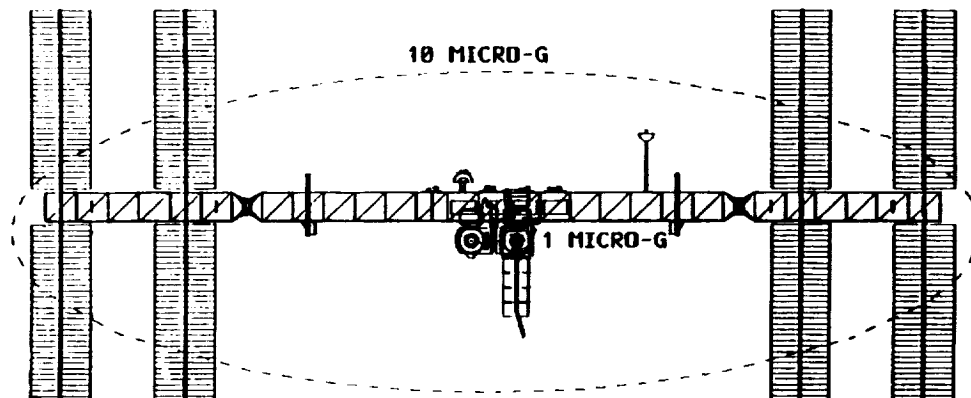
## MICROGRAVITY ENVIRONMENT

<u>SOURCE</u>	<u>LEVEL (G's)</u>
Gravity Gradient	
All payload locations .....	$<10^{-5}$
Some payload locations .....	$10^{-6}$
Atmospheric drag .....	$<0.3 \times 10^{-6}$
Attitude Corrections .....	$<10^{-6}$
Other Disturbances .....	Under study
Docking and undocking	
Mobil Servicing Center	
Crew Exercise	
Reboost	
Solar panel motion	
Fans, pumps, etc	
Crew work activity	
Payloads	

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## MICROGRAVITY ENVIRONMENT



ALTITUDE = 250 NM  
PITCH DRIFT ERROR RATE = .005 DEG/SEC



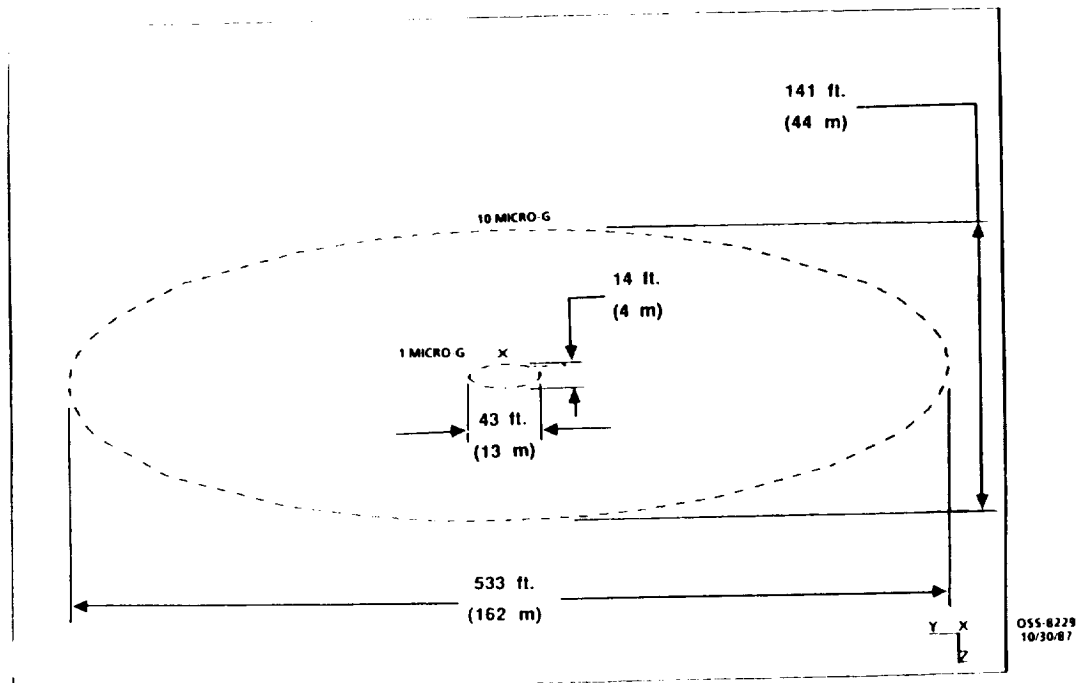
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NASA  
Space Station

## MICROGRAVITY ENVIRONMENT



NASA  
Space Station

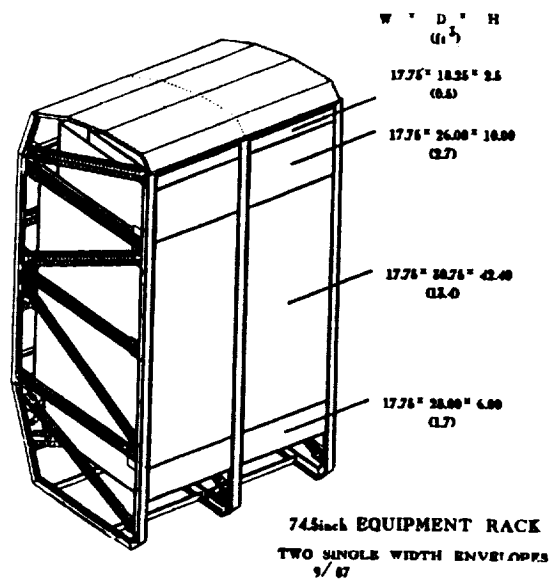
## MECHANICAL INTERFACE - PRESSURIZED VOLUME

- Rack configuration
  - Double rack scheme
  - 42" wide x 74.5" high x 36" deep (65 cubic feet)
  - Interface to user: Standard 19", drawers per EIA-R5310C, or Double width drawers without center post
- Double racks available to US users: 45
  - US Lab Module: 29
    - ~9 for Station-provided lab support equipment and facilities e.g. gloveboxes, workbench, x-ray system, incubator, freezer, washer, cameras, etc
    - ~20 for user-provided experiments and support equipment
  - ESA Columbus Module: ~ 10
  - Japanese Experiment Module: ~ 6

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## DOUBLE RACK CONFIGURATION



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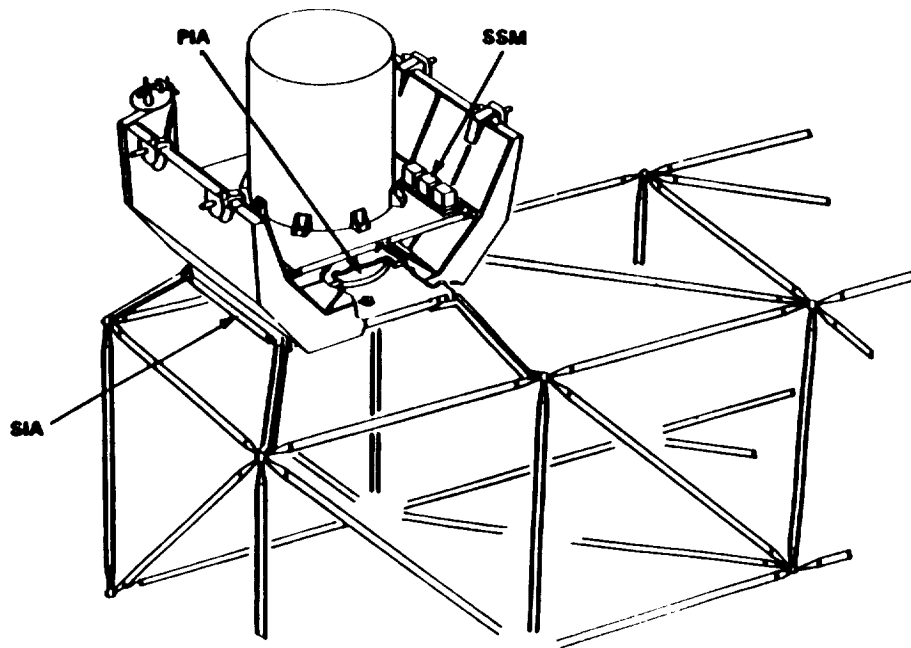
## MECHANICAL INTERFACE - EXTERNAL ATTACH POINTS

- Four utility parts available on truss
  - Utilities available: power, command and data, video and high rate data, thermal control, GN&C data, etc
- Two sets of payload attach equipment provided, including:
  - Station interface adapters
  - Payload interface adapters
  - Deck carriers
  - Multiple payload adapters
  - System support module
- Payload Pointing System
  - Three axis pointing
  - CG Yoke design
  - Stability: thirty arc seconds peak-to-peak
- Additional small attached payload accommodations are under consideration

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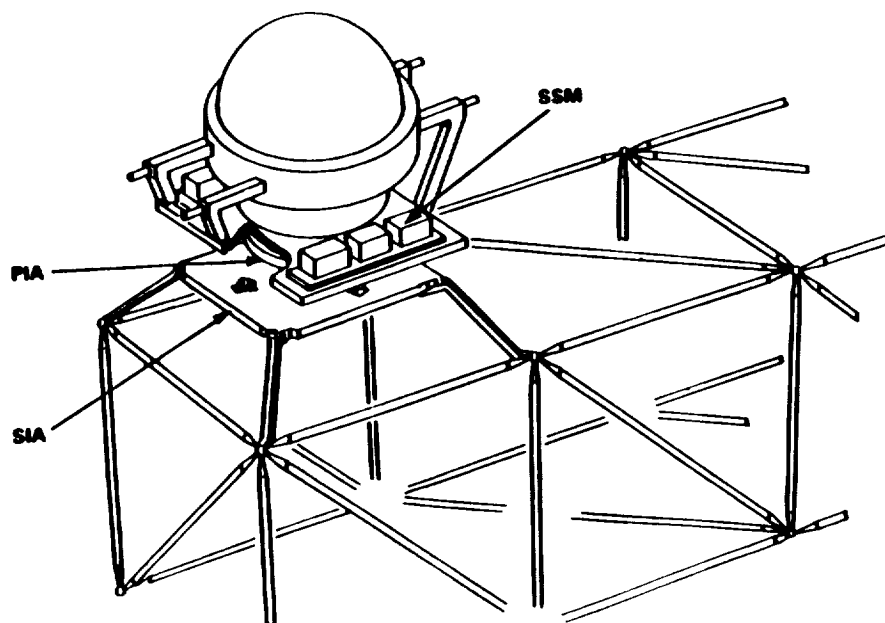
## ATTACHED PAYLOAD - PALLET CARRIER



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## ATTACHED PAYLOAD, UNIQUE CARRIER

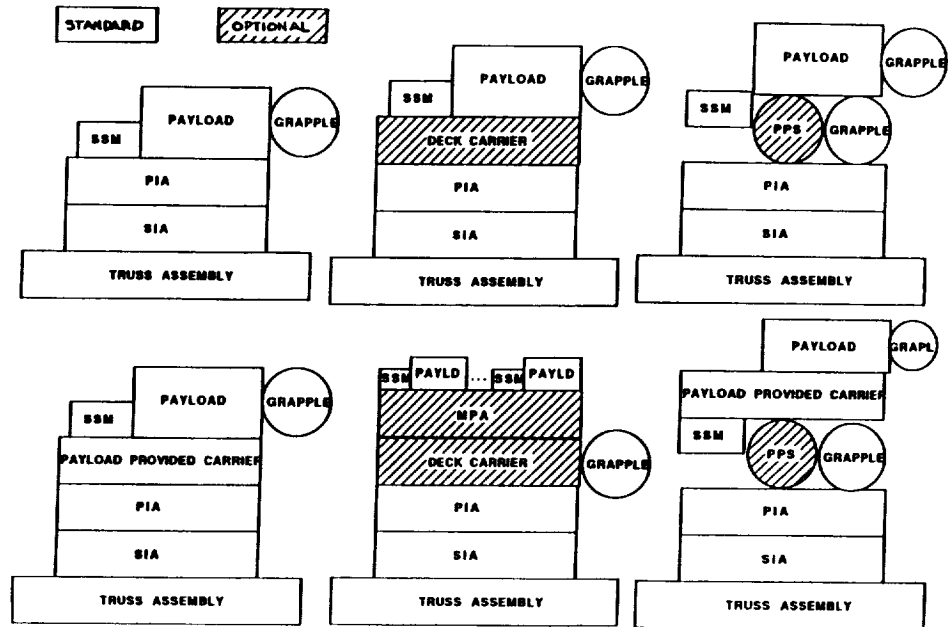


OS5-8241  
10/30/87



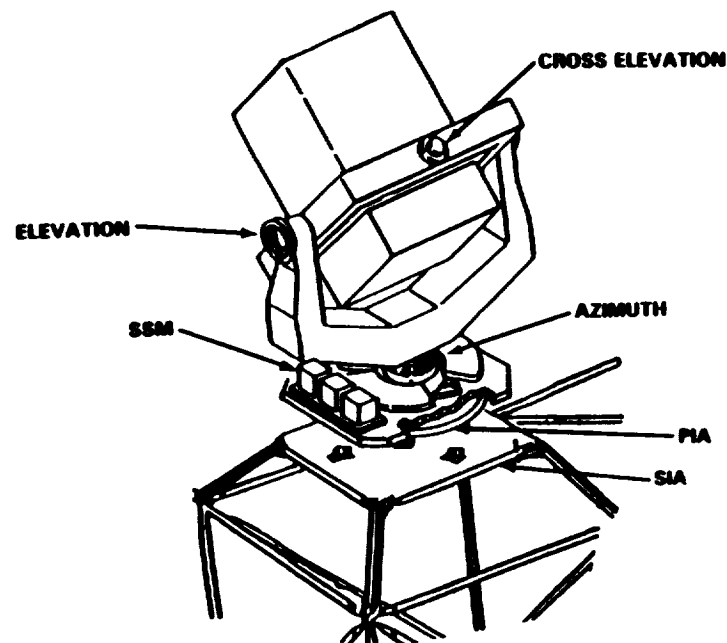
NASA  
Space Station

## ATTACHED PAYLOAD ACCOMMODATIONS EQUIPMENT STRUCTURAL/MECHANICAL SYSTEM ARCHITECTURE



OSS-8226  
10/29/87

## ATTACHED PAYLOAD ON PAYLOAD POINTING SYSTEM



OSS-8243  
10/30/87



## POWER SYSTEM

---

- Total power available - 75kw
- User power available - 45kw
- Main bus - 440 volts, 20KHz, single phase
- Direct user interface - 208 volts, 20KHz, single phase
- Station - provided converters at each payload
  - 120/208 volts, 60 hz, single phase
  - 28 volts dc
  - User charged for conversion losses
- Maximum available at one double rack
  - 15kw at six special double racks
  - 3kw at all other double racks
- Maximum available at one external attachment point
  - 10kw for payload
  - 2 kw for Station-provided subsystems

OSS-8213  
10/30/87



## THERMAL CONTROL SYSTEM

---

- Heat rejection capacity for user - 45kw
- Attached payload interface - cold plates
- Rack interface
  - 20% of racks - cold plates
  - 80% of racks - air cooling
    - Via rack plenums (no ducts)
    - Air temp: 50-110° F
    - Air flow: 25-210 CFM

OSS-8225  
10/29/87



## DATA MANAGEMENT SYSTEM

---

- Provides communication path transparent to users
- Allows remote control and monitoring of payloads
- Provides common crew interfaces
- Employs local area networks and local buses
- Data link formats
  - Serial links
  - International standards will be used
  - Low rate example - RS 232 at 9600 baud
  - High rate example - MS 1553 at 1 Mbs
- Maximum data rates
  - At attached payload ports: 10 Mbs
  - At racks: 1-100 Mbs, depending on rack

OSS-8223  
10/30/87



## HIGH RATE DATA AND VIDEO

---

- Maximum total data rate from manned base: 300Mbs
- High rate data handled separate from DMS system
- Maximum digital data rates
  - At attached payload ports: 50 Mbs
  - At racks: 50 Mbs
  - Interface: Space to ground signal processor
- Analog video
  - Digitization, compression, and frame grabbing provided at the Signal processor
  - Interface format: component video

OSS-8223  
10/30/87



## CREW RESOURCE FOR USERS

---

- Eight Person crew at Phase 1 completion
- Two four -person shifts per day
- Nine hour workday, six days per week
- Approximately three people per shift available for users
- EVA: eighteen hours/week, shared between users and station

OSS-8217  
10/30/87



## PAYLOAD TRANSPORTATION ACCOMMODATIONS

---

- Pressurized Logistics Carriers
  - Both rack and non-rack accommodations available
  - Refrigerator or freezer provided
  - Life sciences accommodations in a controlled environment
- Unpressurized Logistics Carriers
  - Both rack and non-rack accommodations available
  - Accommodations for dry cargo and fluids
- Deck Carriers
  - For use with external attached payloads
- Upmass available to all users
  - During Phase 1 construction: ~77,000 lbs
  - After Phase 1 completion: ~50,000 lbs/year

OSS-8216  
10/29/87



## POLAR PLATFORM

---

- **Orbit parameters**
  - Altitude: 824kw
  - Inclination: 98.7 deg
- **Attitude**
  - Orientation: LVLH
  - Stability: .002 deg
- **Payload capacity**
  - 3000 kgm (Titan IV or ASRM STS)

OSS-0220  
(2 of 2)  
10/30/07



## POLAR PLATFORM

---

- **Power**
  - 2.5kw total
  - 1.1kw for users (208v, 20KHz)
- **Data rate**
  - 300 Mbps
  - S-band and Ku-band over TDRSS
- **Thermal Control**
  - Dissipation for user: 1.1 kw
  - Cold plates and radiators

OSS-0220  
(2 of 2)  
10/30/07





## **OSSA SPACE STATION INITIATIVE PRINCIPLE AREAS**

---

- Life sciences
- Microgravity research
- Earth science on polar platform
- Attached payloads

OSS-7709  
10/29/87



## **OSSA SPACE STATION INITIATIVE LIFE SCIENCES**

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- Operational certification is required for extended crew time on Space Station
- Life science research will be a principle activity on Space Station
- Near term initiatives
  - Detailed planning for extended duration crew time (180 days + ) and associated biomedical research facilities
  - Develop 1.8 M centrifuge through Spacelab to Space Station
  - Detailed planning for additional space biology research facilities

OSS-7710  
10/29/87



## **OSSA SPACE STATION INITIATIVE MICROGRAVITY RESEARCH**

**(MATERIALS SCIENCES, PHYSICS, AND CHEMISTRY)**

---

- **Microgravity research will be a principle activity on Space Station**
- **The space-research community and their facilities need development**
- **Near term initiatives**
  - **Develop facilities through Spacelab to Space Station**
  - **Planned facilities:**
    - **Modular Multizone Furnace Facility**
    - **Modular Combustion Facility**
    - **Fluid Physics and Dynamics Facility**
    - **Modular Containerless Processing Facility**
    - **Advanced Protein Crystal Growth Facility**
    - **Biotechnology Facility**

OSS-7711  
10/30/87



## **OSSA SPACE STATION INITIATIVE EARTH SCIENCES**

---

- **The Earth Observing System (EOS) will be principle user of polar platform**
- **A major step in "planet earth" initiative**
- **Will provide long-term observations needed to understand the natural earth system**
- **Will help prediction capability of natural and man-made changes**
- **Instrumentation from NASA, NOAA, ESA, and Japan**
- **Near term initiative**
  - **A O in Jan 1988**
  - **New start in Oct 1990**
  - **First launch in Oct 1995**

OSS 7712  
10/30/87



## OSSA SPACE STATION INITIATIVE ATTACHED PAYLOADS

---

- Offer opportunities to astrophysics, solar terrestrial physics, earth sciences, and solar system research
  - Station provides unique combination of accommodations
    - Long term observations
    - Accessibility and serviceability
    - Capacity for large payloads
  - Instrument definition program underway
- Examples:
- Plasma Interaction Monitoring System (PIMS)
  - Cosmic Dust Collector Experiment (CDCE)
  - Earth Radiation Budget Experiment (ERBE)
  - Large Area Modular Array of Reflectors (LAMAR)
  - Laser Communication Engineering Test
  - Astrophysics Hitchhiker
  - Solar Terrestrial Observatory/Solar Instrument Group
- Attached payloads can be accommodated on Launches 3, 4, 14, and 17

OSS-7713  
10-30/87



## RAPID RESPONSE RESEARCH

---

- Wide-spread user interest in this capability
  - Science, Applications, Technology, Commercial
- Rapid means 6-24 months from approval to launch
- The challenge: Minimize perturbations to the "system"
  - Reserve resources
  - Standardize interfaces
  - Obtain strong top level management commitment
  - Establish efficient working-level management structure
- Efforts are underway to crystalize this concept, by:
  - Office of Space Station
  - Office of Space Science and Applications
  - AIAA

OSS-8215  
10-30/87

## **SPACE STATION UTILIZATION AND OPERATIONS**

Mr. Richard E. Halpern, Director, Utilization and Operations Division, provided a briefing on the plans for the Space Station utilization and operations. Key points in Mr. Halpern's remarks were:

- NASA wants industry participation in the Space Station program.
- NASA and industry must be understanding and flexible in forging the new relationship. Both must recognize that difficulties will exist at times.
- Industry needs to tell NASA what it needs to get into the business and NASA will try to provide it.
- An industry association will be formed to assist NASA in the commercial space program. More information will be forthcoming.
- NASA recognizes that there are many unresolved issues such as resource allocation which includes transportation, operations, pricing, and liability, and is working to address those issues and get them resolved quickly.
- There will be significant follow-up activities from this Workshop.



National Aeronautics and  
Space Administration

## **SPACE STATION UTILIZATION AND OPERATIONS**

**RICHARD HALPERN  
DIRECTOR  
UTILIZATION AND OPERATIONS DIVISION**

**NOVEMBER 4, 1987**

## **CURRENT SITUATION**

---

- **NASA has been in business for 30 years and has established certain ways of doing things**
- **However, NASA has never built anything like the Space Station before**
- **Therefore, NASA must:**
  - **Draw on its past experience**
  - **Be flexible in its approach (i.e., be willing to do it in a different, better way in the future when that is appropriate)**
  - **Be able to deal with the resultant cultural conflicts when these two clash**

OSS-8231  
Pg 1 of 2

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## **CURRENT SITUATION (Continued)**

---

- **In dealing with industry, NASA needs to:**
  - **Be open to ideas and not make commitments either way early in the activity**
  - **Appreciate the different perspectives, review each impartially and, hopefully, develop the best possible approach**
  - **Be open to ideas, suggestions and approaches presented by industry**
- **In dealing with NASA, industry needs to:**
  - **Understand that NASA's approaches and methods are based on extensive experience in space programs and change will happen only if benefits to NASA can be shown**
  - **Appreciate that NASA's methods differ from commercial methods and work toward mutual understanding**
  - **Be open to ideas, suggestions and approaches provided by NASA**

OSS 8231  
Pg 2 of 2

## **WHAT MAKES SPACE STATION DIFFERENT**

---

- **Most prior space activity (Mercury, Gemini, Apollo, Voyager, etc.) were missions (had a start, middle and an end)**
- **Space Station is an operational system that will be built upon, improved and expanded over an extended period (30 years or more)**
- **Space Station must be approached as a "going concern" rather than as a "mission"**
  - **Respond to future requirements**
  - **Upgrade technology**
  - **Build on experience**

OSS 8232  
10/30/87

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## **SPACE STATION OPERATIONS PLANNING**

---

- **Space Station Program has been developing concepts and approaches to both utilization and operations for the last two years**
  - **Results of this work form Space Station's current operations approach**
- **Space Station Program remains open to ideas and alternative approaches**
  - **Program has been and continues to seek industry input into this process**

OSS 8233  
10/30/87

## **SPACE STATION COMMERCIAL UTILIZATION PROGRAM**

---

- **Goal is to develop an informed user community and influence Space Station technical capabilities and operational policies**
  - Commercial inputs are continuously being examined for incorporation in Space Station design
- **Process to facilitate commercial utilization is being developed**
  - Encourage R&D activities in preparation for commercial utilization of the Space Station
  - Support commercial outreach and marketing activities
  - Identify and develop Space Station operational policies and procedures which will accommodate commercial users
  - Promote industrial network to assist NASA in planning for the commercial utility of the Space Station

OSS-3034  
10/29/87

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## **SPACE STATION: FOCUS ON USER REQUIREMENTS**

---

- **Commercial users have had major influence on Space Station design**
  - U.S. materials lab module placed in optimum microgravity environment
  - Standard earth-like atmosphere retained to allow use of existing equipment and facilities
  - Long-term crew presence to interact with space experiments
  - Standardized user support equipment and user interfaces designed to promote user friendly access
  - Accommodations for protection of proprietary information
  - Platform modularity designed for flexibility, servicing and growth
  - Increase power level to meet projected commercial needs
- **Space Station's manned base and platforms will provide new opportunities for commercial endeavors in space**

OSS-3046  
10/29/87

## **PROPOSED: SPACE STATION INDUSTRY ASSOCIATION**

---

- **Industry Association charter and objectives will:**
  - **Assist NASA in planning the commercial utility of the Space Station**
  - **Act as focal point for commercial input into Space Station activities**
  - **Review commercial requirements for input into Station design, development and operations**
  - **Develop a stronger working relationship between the Space Station and U.S. Industry**
- **Membership Characteristics**
  - **Representation from a cross section of U.S. Industrial sector**
  - **Membership drawn from corporate decision makers, technical managers and scientists**
  - **Industrial focus on the opportunities of doing business in space**

OSS 2391  
10/29/87

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## **SPACE STATION OPERATIONS CHARACTERISTICS**

---

- **Space Station operations differ from past experience**
  - **Permanent operations**
    - **Long-term on-orbit servicing and maintenance**
    - **Multiple large scale activities**
    - **Utilization flexibility**
    - **User crew autonomy**
    - **Commercial participation**
  - **Multi-partner international involvement**
    - **Resource sharing**
    - **Cost sharing**
    - **Multiple operations infrastructures**
  - **Evolution**
    - **Capability expansion flexibility**
    - **Partnership flexibility over time**
    - **Branching**
    - **Transportation systems**
  - **Emphasis on reduced operating costs**

OSS 8234  
10/29/87



## **SPACE STATION OPERATIONS PERFORMANCE GOALS**

---

- **Provide an environment for productive, multi-user exploitation of the Space Station which:**
  - **Is safe**
  - **Is accessible**
  - **Is readily accommodating to users**
- **Provide an effective international partnership**
  - **Responsible and mutually supportive**
  - **Equitable**

OSS B/15  
10/30/87

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## **UNRESOLVED ISSUES**

---

- **Program is working to develop policies in the following areas:**
  - **Resource allocation including transportation**
  - **Operations**
  - **Pricing**
  - **Liability**
- **Work is ongoing but much remains to be done**
- **Realize the importance of addressing these issues early and are targeting to resolve them quickly**
- **We need industry perspective, ideas, and comments**

OSS 7973  
10/30/87

## **EXPECTATIONS FOR THIS WORKSHOP**

---

- Identify commercial research, development, services and other opportunities
- Provide input to assist the updating and revision of the database used to define the Space Station requirements (MRDB) to insure commercial activity is properly represented
- Identify issues of commercial concern
- Provide industry options on how to deal with these issues
- Identify activities and actions to be accomplished by NASA prior to the next workshop

**NASA IS SEEKING INDUSTRY PERSPECTIVE, IDEAS AND COMMENTS ON HOW TO MAKE SPACE STATION VALUABLE TO INDUSTRY**

USS 8236  
10-10-87

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## **FOLLOW-UP ACTIVITIES**

---

- Boeing/Peak Marwick Commercial Outreach
- Space Station Industry Association
- Other meetings, symposia and conferences (e.g., AIAA/NASA Space Station Utilization meeting March 7-9, 1988)

USS 8237  
10-10-87



## SPACE RESEARCH APPLICATIONS PROGRAM

Dr. Chris J. Podsiadly provided the Workshop with a briefing on the 3M Corporation experience in the space program. Dr. Podsiadly outlined the 3M/NASA Space Program over the past three years. In his remarks, he summarized 3M's space history, research, direction, and strategic plan; stressed the importance of research in space; and asked who the space racers are and if they are competitors to your business. Other key points and topics in the presentation were:

- The 3M Space history from the Memorandum of Understanding (February 1984) to the first of three flight experiments (November 1984) to the ten-year JEA with NASA (December 1986) that established Space Research and Applications (SRA) program (October 1987).
- The importance of research in space: properties of space, nation's commitment to build Space Station, foreign/domestic competitors.
- The first product is knowledge. Commercialization begins when one decides what to do with this knowledge pool and how it is put together later on in the development of technology or a product.
- The national and international competitors in space materials/material processing of inorganics, organics biotechnology, and commercial uses of space.
- The SRA long range research goal using a 3-phase approach: science, applied research and development, and product development. 3M is still at phase one and building up a science base.
- Areas of development: establish a data base that identifies technical areas; develop technologies and apparatus; foster government, university and other institutional interactions; and develop hardware lease and specialty service businesses.
- The ten year JEA Master Agreement for research and development in organic and polymer science is necessary for continuity of program and accessibility of the environment to do the work.
- Outlined the research direction in Ordered Organics and discussed a strategic plan encompassing new knowledge, improved processes and space involvement by the year 2000.
- The on-going space experiments include Physical Vapor Transport of Organic Solid (1988), Polymer Morphology (1989), and United States Materials Lab (1990).
- The SRA commitment to fly, to develop, and to contribute. Mr. Podsiadly urged U.S. private industry to get together and shake hands with the future that space has to offer.

# 3M/NASA SPACE PROGRAM

3M/NASA 1

## 3M Space History

- Announced Memorandum of Understanding with NASA (Feb., 1984)
- Signed Two-Year Joint Endeavor Agreement with NASA (Sept., 1984)
- Flew Diffusive Mixing of Organic Solutions (DMOS) Experiment (Nov., 1984)

3M/NASA 3

## **3M Space History (cont.)**

- **Flew Third Space Experiment on Crystal Growth (Nov., 1985)**
- **Announced Ten-Year Joint Endeavor Agreement with NASA (Dec., 1985)**
- **Established SRA Program (Oct., 1987)**

**3M/NASA 5**

## **3M Space History (cont.)**

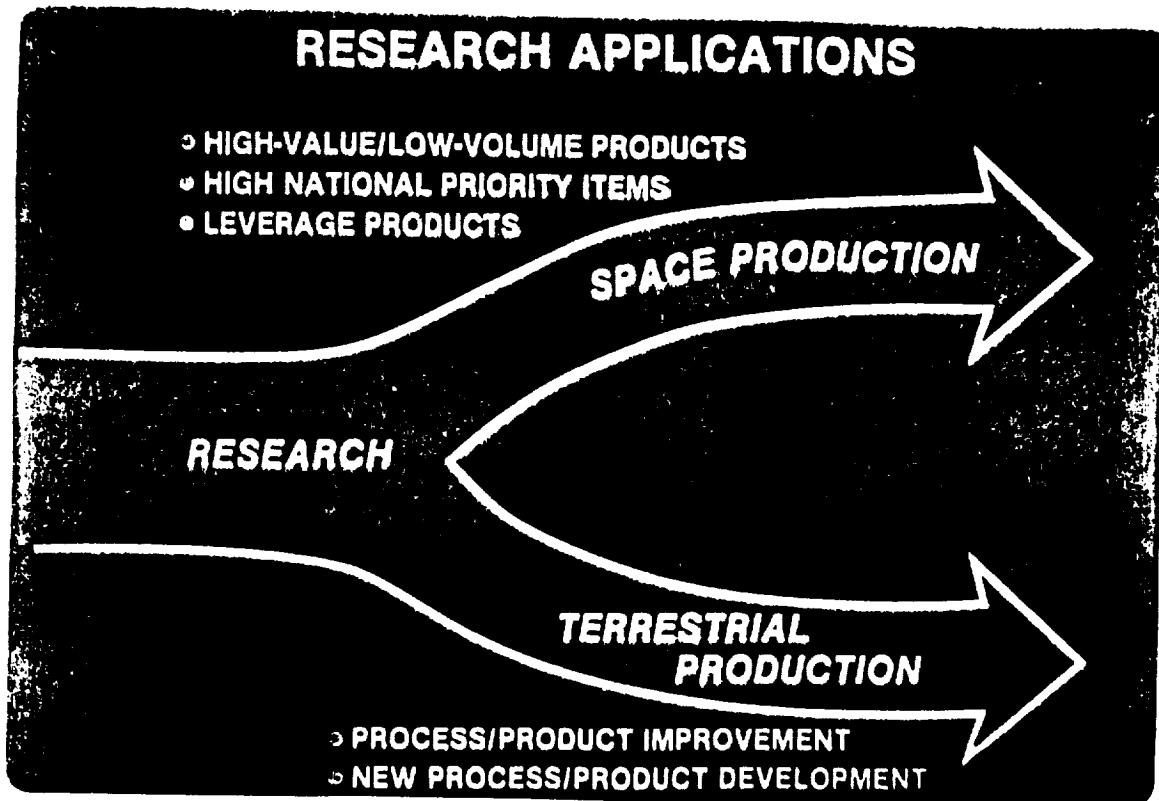
- **Established Space Research and Applications Laboratory (Jan., 1985)**
- **Announced 3M/GM Experiment (Mar., 1985)**
- **Flew Physical Vapor Transport of Organic Solids (PVTOS) Experiment (Aug., 1985)**

**3M/NASA 4**

# Why Research In Space?

- Unique Properties of Space
- Compatibility with Ground-Base Research
- Availability of Space Shuttle
- Nation's Commitment to Build the Space Station
- Incentives for Commercial Use of Space
- Foreign/Domestic Competitors

3M/NASA 6



# Value: Knowledge

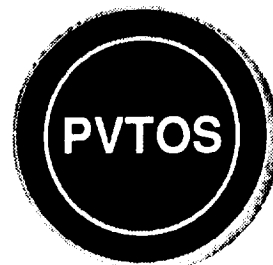
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## In the Beginning . . .

### Science Research Laboratory

**Advanced  
Optics**

**Surface  
Science**



# Competition In Space Materials/Material Processing

## Inorganic

Boeing  
Rockwell  
Grumman  
John Deere  
GM  
TRW  
KMS Fusion  
EG&G  
Westinghouse  
MRA

## Organic

3M  
Rockwell  
CCDS  
(GM)  
(Dow)

## Bio

CCDS  
Upjohn Co.  
Hoffman -  
LaRoche  
Schering  
Merck Institute  
Scripps Clinic  
& Res. Labs

## OUS

Germany  
ESA  
Japan  
China

3M/NASA 7

China Japan  
Europe  
U.S. ???  
Russia ???  
Space Racers



# **SRA LONG RANGE RESEARCH GOAL**

**Science**



**Applied R & D**



**Product Development**

---

## **Areas of Development**

- **Establish a Data Base for the Identification of Technical Areas**
- **Develop Technologies and Apparatus for Space Experiments**
- **Foster Interactions with Government, Universities, and Other Institutions**
- **Develop Hardware Lease and Specialty Service Business**

# **10-Year JEA Master Agreement**

**Basic R & D ➡ Technology Development ➡ Product Development**

- R&D in Organic and Polymer Science - 3M owns Research Projects including Equipment, Materials and Processes
- 62 Flight Experiment Opportunities (FEO)

3M/NASA 11

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## **10-Year JEA Master Agreement (cont.)**

- NASA Provides Standard Services Associated with each FEO
- 3M has lead time for Patent Filing before Public Disclosure of Results
- NASA Scientists can work with 3M Scientists and use 20% of 3M's Equipment (Quid Pro Quo)

3M/NASA 12

# **10-Year JEA Master Agreement (cont.)**

- **NASA Indemnifies 3M for Third Party Liability Insurance Coverage with \$250K Deductible**
- **Appointment of Joint Endeavor Manager (Director of SRA and appointed NASA Manager)**

3M/NASA 13

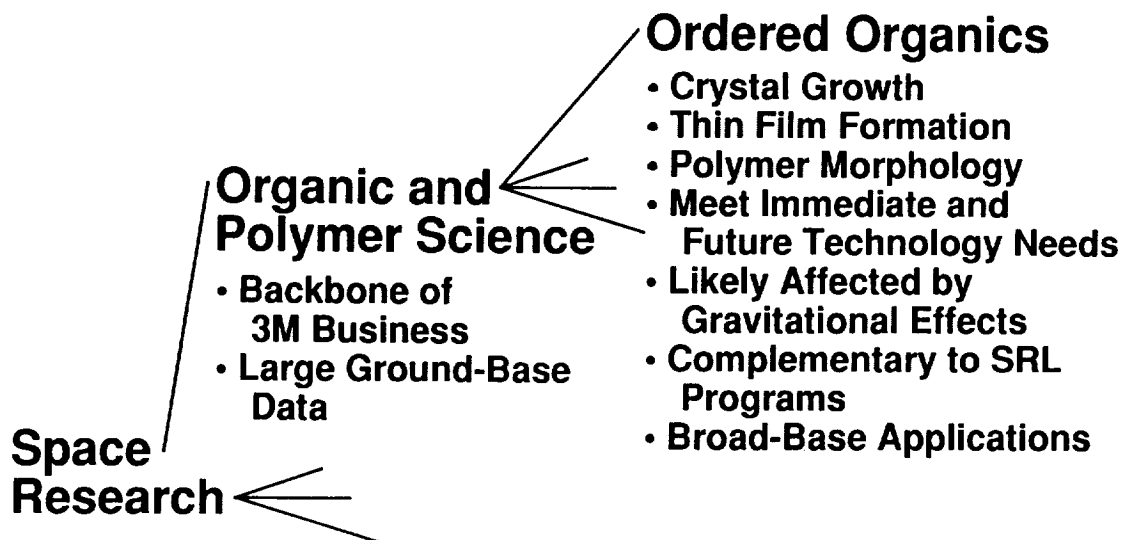
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## **Task Agreement - Technical Working Document**

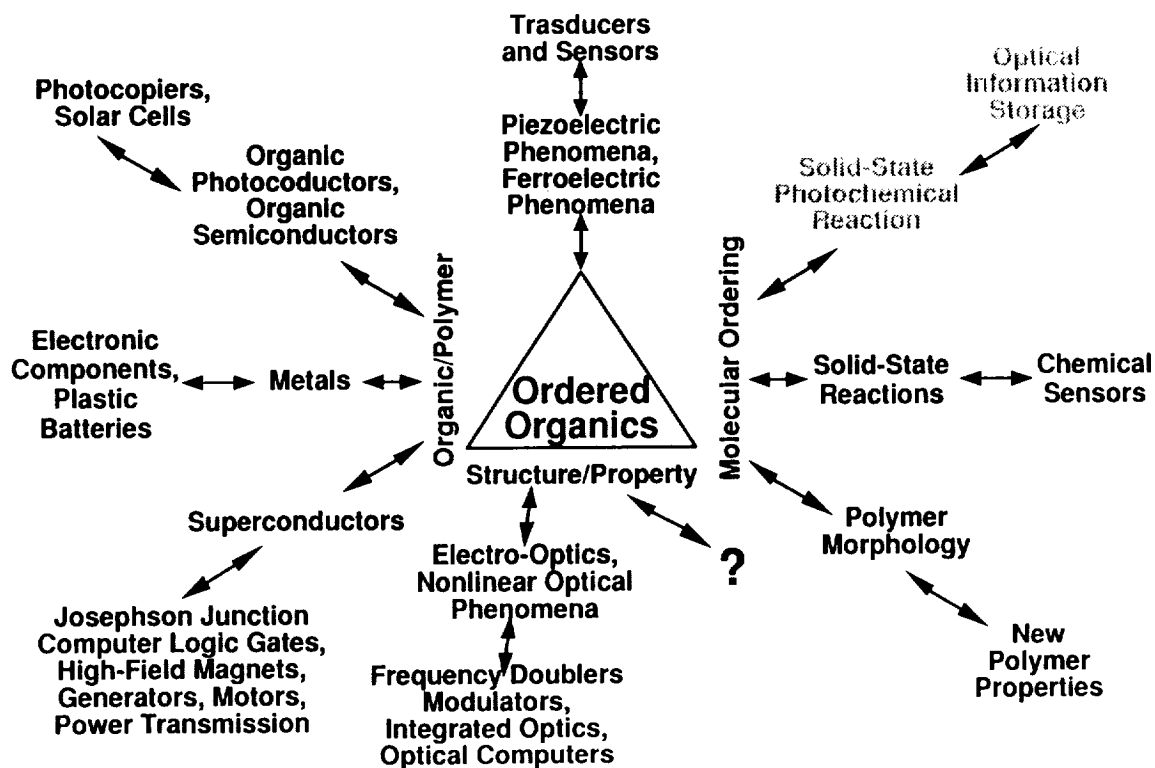
- 1. Define Nature and Scope of Research Topics**
- 2. Sequential Distribution of FEO According to 3M needs**
- 3. Specifics of 3M/NASA Responsibilities**
- 4. Identification of Personnel in the Proposed Project**

3M/NASA 14

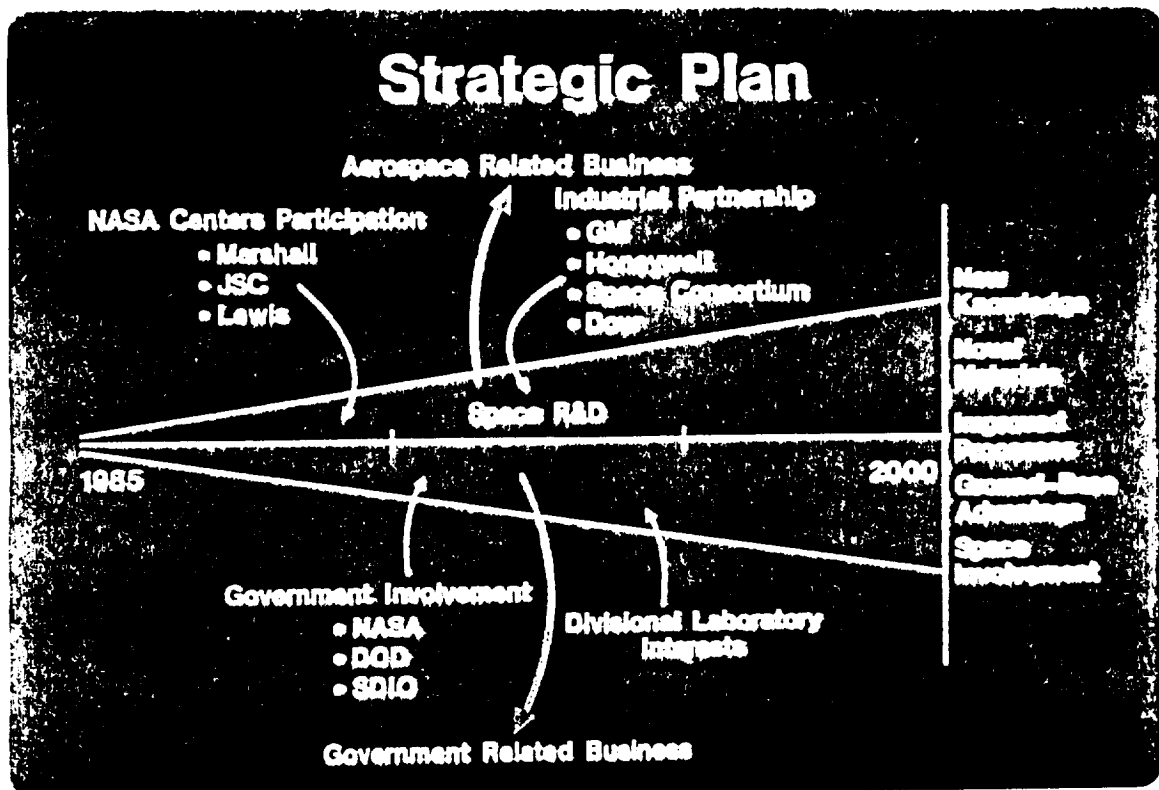
# Research Direction



3M/NASA NEW1



3M/NASA NEW2



## 3M Space Research And Applications Program

# On-Going Space Experiments

- **Physical Vapor Transport of Organic Solid (PVTOS-2) - 1988**
- **Polymer Morphology (PM-1) - 1989**
- **United States Materials Lab (USML-1) - 1990**

3M/NASA 10

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## SRA Commitment

<b>To Fly -</b>	<b>Our Experiments</b>
<b>To Develop -</b>	<b>Significant Scientific Breakthroughs for the Development of Unique 3M Products</b>
<b>To Contribute -</b>	<b>To the Solid Foundation created by NASA and Dedicated Contractors for the Betterment of the U.S. and Mankind</b>

3M/NASA 15



## INDUSTRY WORKING GROUP OVERVIEW

Prior to the Workshop three Industry Working Groups (IWG) were established. The Industry Working Group charters were:

- To identify problems confronting their particular industry sector.
- To present issues at the Workshop for consideration.
- Assign working level people as Workshop participants.

During the Workshop, each Industry Working Group presented its perspectives of the technology needs and issues facing its industry over the next decade. The three working groups were:

- Extraction (Mining, Agriculture, Petroleum, Fishing, Etc.)
- Fabrication (Manufacturing, Automotive, Aircraft, Chemical, Pharmaceutical, Electronics)
- Services (Communications, Transportation, Retail Robotics)



## EXTRACTION INDUSTRY WORKING GROUP PRESENTATIONS

- Introduction: Major Industrial Issues for the Extractive Industries for the 1990's--An Overview  
F.B. Henderson III, Geosat, Panel Chairperson
- Mining Industry  
F.B. Henderson III (William Griffiths), Hecla Mining Company
- Petroleum Industry  
Floyd Sabins (Ted Jones), Chevron Research
- Forest Products  
David Hyink (Norm Johnson), Weyerhaeuser Company
- Agriculture Industry  
Bernard Sanders, Farmland Industries, Inc.
- Engineering Industry  
Cole McClure (James Van Hoften), Bechtel National, Inc.
- Common Themes & Questions  
F.B. Henderson III

## MINING

- Detection of new resources (non-renewable)
  - Remote sensing limited in U.S. (mature); more useful non-U.S.
  - New technology
    - Direct detectors ("indicator minerals")
    - Depth penetration
    - Industrial minerals (transportation dependent) surface operations
  - Mineral access government lands
- Improve competitiveness (cost reduction) (labor costs) Robotics - hard rock, soft rock (coal, uranium, salt)
  - Underground mining
  - Surface mining
  - Environmental cost (i.e. acid rain)
    - Research
    - Meeting standards
- Price of metals (global)

## PETROLEUM

- Price of Oil
  - Economic intelligence
  - Global
- Exploration Risk (Reduction)
  - On-shore
    - Complex deep structures detection (Subsurface)
    - Stratigraphic traps detection
  - Non-U.S.
    - Mapping
    - 3rd party negotiation
  - Off-shore (Leasing)
    - Detection
  - Direct indicators
    - Hydrocarbons/including depth penetration
- Production
  - Enhanced Oil Recovery (EOR)
    - Water
    - Steam
    - Chemical floods
    - Resources -- Reserves
  - Continuity
    - PTV
  - Deep offshore platform/drill structures
  - Environmental impact on-shore/off-shore

## Petroleum Applications of Satellite Remote Sensing

- Exploration
  - Remote Sensing Primarily Used in On-shore Areas
  - Especially Useful in Foreign Areas
  - Regional Geologic Mapping
  - Aid Geophysical Surveys
- Production
  - Provide Base Maps
  - Identify Access and Trafficability
  - Pipeline and Facility Planning
  - Off-shore Applications

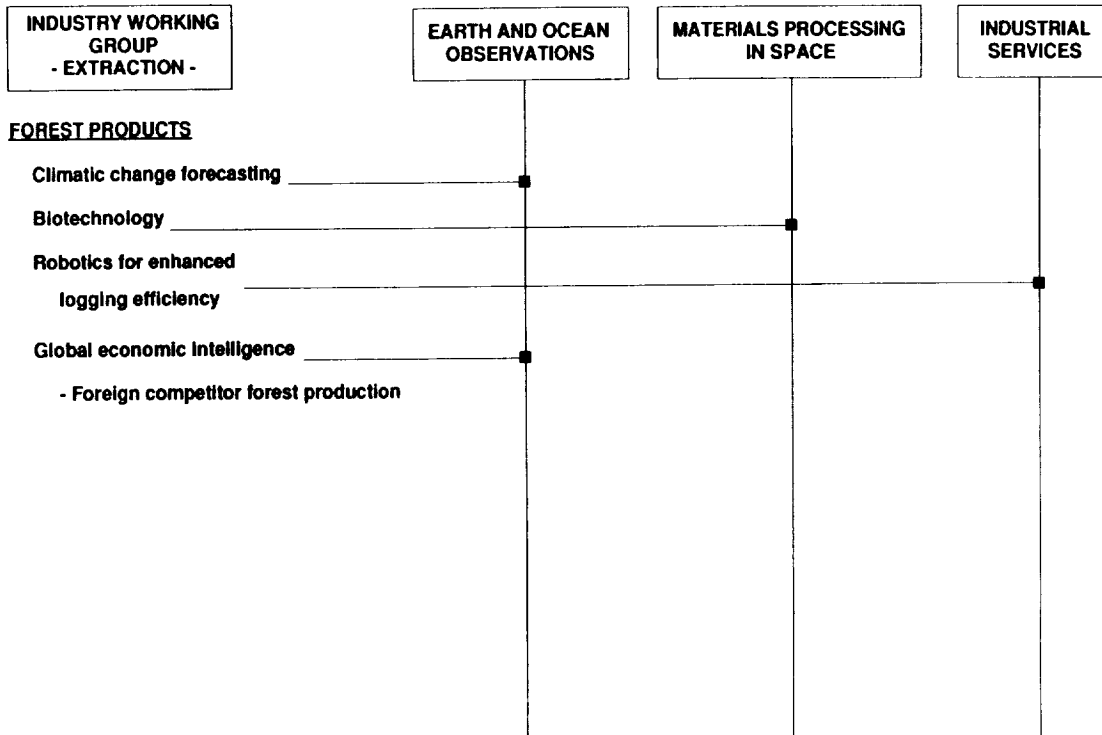
## FOREST PRODUCTS

- Product quality
  - Sensor systems and applications
    - Raw materials
    - Chemical recovery
- International economic intelligence
  - Competition monitoring/evaluation
  - U.S. economic information data base (U.S. economic modeling)
  - U.S. forest inventory (monitoring)
    - Growth
    - Quality
    - Yield
    - Storms
    - Insects
    - Diseases
    - Fire detection/prediction
    - Government cuts
- Effects of climatic change
  - Acid rain, gases, chlorophyll
  - Temperature increase (greenhouse effect) Validation vs. 35 year timber crop lifetime
- Operations (cost cutting/savings)
  - Timber hauling (robotics)
  - Residue handling, waste (black liquor)
  - Siting - waste, toxic waste(s) disposal, incinerators

## Integration of Industry Issues into Space Panels



Boeing  
Peat Marwick





# **GLOBAL ISSUES**

**IN**

# **AGRICULTURE**



## **Effects Everyone**

- Consumers
- Producers
- Government Policy Makers
- Supporting Industries

### Common Objectives

- Improved Quantity and Quality of Food
- Efficient Utilization of Resources
- Adequate Incomes to Producers
- Security of Supply
- Affordability

### Unique Characteristics

- Necessity
- Impacted by Nature
- Perishable Product
- Renewable Resources
- Inelastic Demand
- Inelastic Short-Term Supply
- Elastic Long-Term Supply
- Seasonal Production Cycles
- Production and Consumption World-Wide

## **The Problem**

- Unexpected supply shifts significantly impacted prices, incomes and the geographic availability of food.
- Short-term market information results in a long-term misallocation of resources.

## **The Need**

- Timely - accurate information on a global basis.
- Long-term food production capacity projection
  - For investment decisions
  - For policy decisions
- Short-term supply and availability information
  - For production decisions
  - For trade decisions

## **Long-Term Food Production Capacity**

- By major product groupings
- By geographic distribution
- Changes (total and distribution)
  - Relative to population
  - Relative to political control

## **Advance Monitoring of Causes of Change**

- Climatic shifts
- Water quality and availability
- Soil Erosion
- Excess harvest
- Environmental damage
- Land use changes
- Change in reproductive stock
- Reclamation and conservation
- Energy availability
- Chemical plant nutrient availability

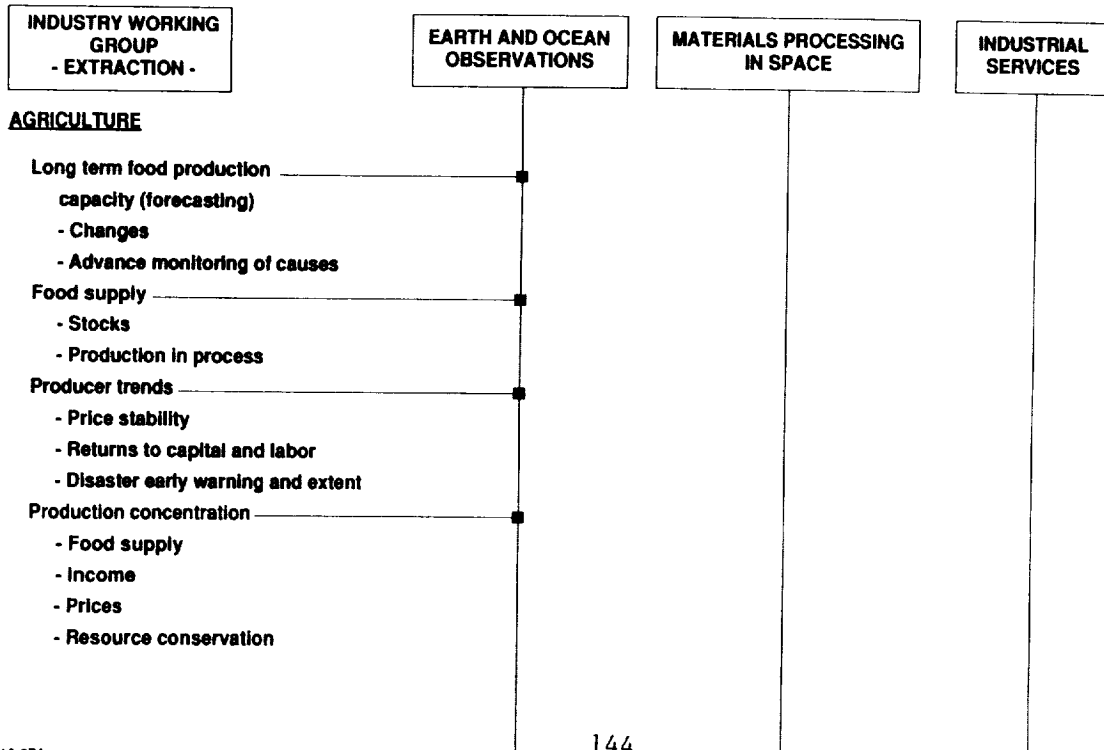
## Food Supply

- Stocks
  - Quality
  - Geographic Distribution
- Production in process
  - Monitoring of acreage and yields
  - Weather forecasting - impact on harvest
  - Monitoring of fish harvest

## Integration of Industry Issues into Space Panels



Boeing  
Peat Marwick





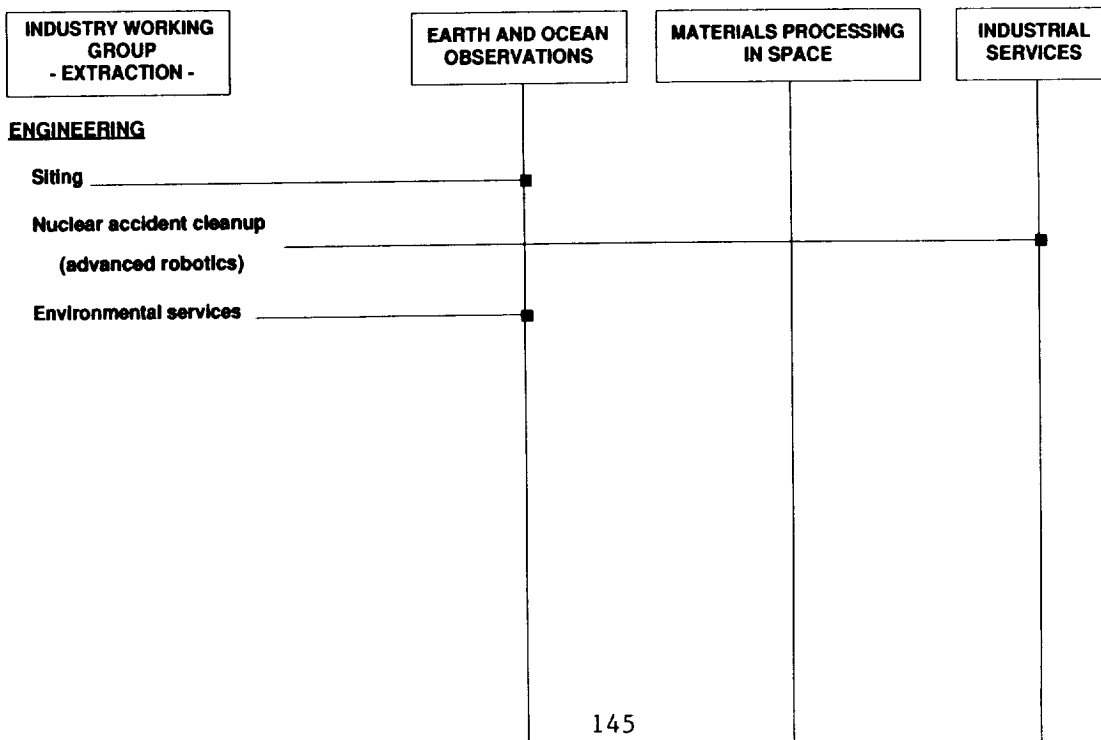
## Engineering - Construction

- Siting
  - Construction - dams, harbors, roads, nuclear sites, nuclear wastes, toxic wastes, pipelines, mines
  - Extraterrestrial (future) - constructing and engineering
- Power
  - Pipelines
  - Transmission
  - Power plants
- Robotics
  - Three Mile Island monitoring (radiation)
  - Automation
- International monitoring and intelligence
  - Weather, floods (realtime)
- Environmental (services)
  - EIS (predictive)
  - Monitoring

## Integration of Industry Issues into Space Panels



Boeing  
Peat Marwick



# OPERATIONS

	Petroleum & Mineral Industries	Forest Products	Engineering & Construction	Agriculture
Exploration	X			
Crop Inventory		X		X
Siting	X	X	X	
Production	X	X		X

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# GLOBAL ECONOMIC INTELLIGENCE

	Petroleum & Mineral Industries	Forest Products	Engineering & Construction	Agriculture
Price	X	X		X
Global Resources	X	X		X
Monitoring Competition	X	X	X	X
Monitoring Weather & Disaster		X	X	X
Production & Capacity	X	X		X

# ENVIRONMENT

	Petroleum & Mineral Industries	Forest Products	Engineering & Construction	Agriculture
Meeting Government Standards	X	X	X	
Monitoring Change	X	X		X
Monitoring Disease & Insect Damage		X		X
Siting			X	
Environmental Impact	X	X	X	





## FABRICATION INDUSTRY WORKING GROUP PRESENTATIONS

- Pharmaceutical Industry  
Dr. James Fox, Pharmaceutical Manufacturer's Association
- Biotechnology Industry  
Dr. David McGee, Industrial Biotechnology Association
- Chemical Industry  
Dr. Delbert Meyer, Amoco Chemical Company
- Analytical Instruments  
Mr. John Rehnberg, The Perkin Elmer Corporation
- Capital Equipment Manufacturing  
Mr. Gordon Starr, Cummins Engine Company, Inc.
- Transportation Equipment  
Dr. Edward Trachman, Rockwell Automotive Operations
- Electrical Power Generation  
Dr. Monte Hall, Yin Research Corporation
- Iron and Steel Industry  
Mr. L.W. Lherbier, Cyclops Corp. Cytamp Specialty Steel Division

Note:

Mr. Lherbier was unable to be present at the Workshop. His views regarding the needs of the Iron and Steel industry are set forth in his letter of November 19, 1987.



SPACE STATION WORKSHOP MATERIALS PROCESSING IN SPACE  
(by the Pharmaceutical Industry)

by

J. Lawrence Fox, Ph.D.  
Corporate Molecular Biology  
Abbott Laboratories  
Abbott Park, IL 60064

on behalf of the  
Pharmaceutical Manufacturer's Association

The pharmaceutical industry was interested in the potential of space for commercial applications from early in the development of the space program. The processing of pharmaceutical materials is a significant part of the expense of producing a product. This technology has always been complicated and produced results that are invariably less than are ideally desired. Abbott Laboratories participated in an early experiment on the electrophoresis of cells in the early 1970's (Apollo-Soyuz and STS 8). The Pharmaceutical Manufacturer's Association has maintained a committee to discuss potential applications of space technology for nearly a decade now.

The nature of the pharmaceutical industry has changed in the past decade. In addition to rather traditional small, organic molecules being offered as therapeutic agents, large biological molecules have been developed for therapeutic use. Several pharmaceutical companies have also developed a range of diagnostic products, these primarily being based on the use of antibodies (also called immunoglobins).

During the early phases of thought of commercialization of space, the prospect of using gravity-free electrophoresis for the purification of therapeutic and diagnostic proteins as well as for the separation of cells which might produce such products developed. Initial experiments showed that electrophoresis technology performed somewhat better in space than it did on earth. However, during the past decade some very significant advances were made in separation sciences. The newer chromatography technologies offer far superior resolution, so electrophoresis has not developed as a preparative technology and is utilized today only for analytical purposes.

The development of recombinant DNA technology has also had a significant impact on altering the objectives of the pharmaceutical industry. Whereas a decade ago there was significant interest in fractioning cells to obtain high yield clones, it is now possible to obtain high yields from engineered cells. This greatly reduces the complexity of protein purification procedures.



In summary, the pharmaceutical industry no longer views the use of space and zero gravity environments as an economically viable solution to its production problems. The only applications being seriously considered for space are in the realm of research. The greatest interest lies in using zero gravity environments for protein crystallization. This would assist in the determination of three dimensional structures by x-ray diffraction of proteins for "rational" drug design. Even this technology is being replaced slowly by the use of solution phase nuclear magnetic resonance studies.

The take-home message from this industry is that space offers unique opportunities for research activities, but is not viewed as a suitable environment for production scale processes.

## PHARMACEUTICAL INDUSTRY

### Therapeutics

- Organics
- Biologicals

### Diagnostics

- Antibodies
- DNA probes

## PURIFICATIONS

### Chromatography

(high resolution)

- low pressure
- high pressure

### Electrophoresis

(low resolution)

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## ORGANICS

### Chemical synthesis

### Fermentation

- Complex mixtures
- Organic extraction

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## PROCESSING IN SPACE

### Production

- Impractical
- No advantage

### Research

- Protein crystallization

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## BIOLOGICALS

### Fermentation

### Tissue culture

- Complex media



BIOTECHNOLOGY INDUSTRY  
Dr. David McGee  
Industrial Biotechnology Association

Ladies and Gentlemen:

It is a distinct honor to have been asked to participate in this Space Station Workshop. I regret that I was unavoidably called away at the last moment and very much appreciate Dr. Fox reading these brief introductory remarks to you on my behalf.

As a professional at Biosource Genetics Corporation involved in plant biotechnology research and development, I have been asked by the organizers of this workshop to describe to you in a few minutes major technical problems and needs facing the U.S. biotechnology industry regardless of whether or not space technology may be the solution. In addition, I have been asked to suggest projects for the space station crew to conduct which could directly benefit the biotechnology industry.

The primary problem facing biotechnology is the current lack of identified and isolated genes of commercial importance. To a major extent this is a marketing problem and is not necessarily a technical problem. Plants have received less research over the years than bacterial and animal systems. This is due in a large part because the early days of molecular genetics research was conducted using bacterial and viral systems which were then applied to human health problems. In the past seven years plant genetic research--especially in its application to the agricultural market--has begun to catch up. The major technical problems associated with plant biotechnology are concerned with the development of a routine, efficient transformation system for the delivery of genes, especially to certain monocotyledonous plants (for example, corn). It is not apparent that the unique environment of space will help to solve this problem.

However, if one views plants and plant cells as a major source of vital components in a space life support system, then the question is no longer what can space do for biotechnology, but what can biotechnology do for space? For example, it is clear that the Space Station crew will require a nutritionally complete diet. The development of synthetic or animal sources of carbohydrates have worked in model systems but not enough varieties and flavors are available. This can have a major negative psychological effect during prolonged space voyages. Ordinarily, the agricultural industry has approached varietal and flavor improvement through conventional plant breeding. In space this would involve a mammoth breeding program requiring many decades of working with possibly fifty or more plant varieties with each having to be suited to space station and lunar-type environments. Rather than doing this, the application of advanced biotechnologies to plant improvement should be made. One possible method would be to identify several plant species (for example, a grain, vegetable and fruit) to serve as "workhorses" in space. Part of the selection criteria for these "workhorses" would be the amenability of each plant variety to genetic engineering. Adaptation to bioreactor and lunar soil conditions could be initiated along with the insertion of identified genes coding for flavors and nutritional traits of interest. Instead of taking many decades for plant development and improvement through conventional means, genetic engineering could result in new sources of food materials within a few years of the establishment of a functional space station and lunar base.





In a microgravity or zero gravity environment on board the space station, the most efficient plant source will be a single cell system. Without gravity the plant would not need to expend energy for the development of stems, roots, and so forth. The atmosphere surrounding the plant cells could serve as the nutrient medium. Therefore, there would be no necessity for a complicated liquid medium since the atmosphere could be designed to provide a 100% humidified, nutrient-enriched environment in which the plant cells are suspended. The target would be to develop a cell culture system on the space station. The space station scientists would extract flavors and nutrients from these cell cultures to be blended with the "workhorse" crops grown on the moon during processing.

During the next few years while the space station is being constructed, scientists on earth need to identify specific traits of interest leading to the isolation of corresponding genes. Appropriate plant species should be selected as candidate "workhorses". During the design phase of the space station, facilities should be planned for bioreactors and plant cell growth chambers capable of supporting experiments like those described here.

In conclusion, plant biotechnology can go a long way toward the rapid development of novel sources of crops designed for space. These crops are a mandatory requirement for any significant advancement in prolonged space travel. Genetically engineered crops can provide high quality, flavorful food for space crews as well as numerous other specialty products required by them. Biotechnology clearly a powerful, new technology which will serve space exploration for the foreseeable future.

Thank you for your attention.



## **PROBLEMS FOR THE CHEMICAL INDUSTRY**

1. Maintain Competitive Position in the World Market
2. New Products
3. Environmental Concerns

Dr. Delbert Meyer  
Amoco Chemical Co.

CHAPTER II

# Executive Summary

of  
National Science Foundation  
Report on  
Chemical Industry  
*Recommended by  
Dr. Delbert Meyer*

## SOCIETAL BENEFITS FROM CHEMISTRY

Chemistry provides fundamental understandings needed to deal with many societal needs, including many that determine our quality of life and our economic strength.

### New Processes

The U.S. chemical industry has a current \$12 billion positive balance of trade. Continued competitiveness depends upon constant improvement of existing processes and introduction of new ones. Advances in chemical catalysis and synthesis will be key to maintaining our current position of world leadership. (See Section III-A.)

### More Energy

Ninety-two percent of our present energy consumption is based upon chemical technologies; this will remain true well into the 21st century. However, new chemistry-based energy sources will have to be tapped. They will include low-grade fuels for which better control of chemical reactivity is needed so that we can protect the environment while providing energy at reasonable cost. (See Section III-B.)

### New Materials

The next two decades will bring many changes in the materials we use, including the materials in which we are clothed, housed, and transported. Chemistry will play an increasingly vital role in this interdisciplinary field because advances will depend upon ability to tailor new substances, including polymers, to replace and outperform traditional or scarce materials. (See Section III-C.)



## **EXECUTIVE SUMMARY**

### **More Food**

To increase world food supply, we need improvements in the production and preservation of food, soil conservation, and the use of photosynthesis. In collaboration with contiguous disciplines, chemistry plays a central role as we seek to clarify in detail the chemistry of biological life cycles. Once clarified they can be nurtured and controlled, while undesired side effects are avoided through chemical identification and synthesis of hormones, growth regulators, pheromones, self-defense structures, and nutrients. (See Section IV-A.)

### **Better Health**

All life processes—birth, growth, reproduction, aging, mutation, death—are manifestations of chemical change. Chemistry is now poised to clarify such complex biological processes at the molecular level. Hence it is making important contributions to physiology and medicine through rational drug design and, then, through synthesis of new compounds that promote health and alleviate specific ailments such as atherosclerosis, hypertension, Parkinson's disease, cancer, and disorders of the central nervous and immune systems. (See Section IV-B.)

### **Biotechnologies**

Remarkable progress made in recent years by molecular biologists and biochemists in genetic engineering has been built upon basic chemical principles that determine the chemical structures and functional relationships between molecules and supermolecules (proteins, DNA) within biological systems. Full realization of the potentialities of the projected new biotechnologies will increasingly depend upon molecular-level understandings. Chemists will be active collaborators in the progress toward this goal. (See Section IV-C.)

### **Better Environment**

A major contemporary concern is protecting the environment in the face of increasing world population, urbanization, and rising standards of living. Effective strategies for safeguarding our surroundings require that we know what's there, where it came from, and what we can do about it. Chemistry lies at the heart of the answers to each of these questions: it can provide analytical techniques that give early warning of emerging problems, recognition of their origins, and access to alternative products and processes to ameliorate undesired impacts. (See Section V-A.)

### **Continued Economic Competitiveness**

The value of U.S. chemical sales is near \$175 billion, and we have a positive balance of trade. Preservation of our quality of life depends significantly upon

**EXECUTIVE SUMMARY**

maintaining this position of leadership. Our future competitiveness will be dependent upon staying in the vanguard as the frontiers of chemistry change and upon supplying to industry a stream of talented young scientists who have been working at these frontiers and using state-of-the-art instrumentation. (See Section V-B.)

**Increased National Security**

Key factors underlying national security are a healthy populace and a dynamic, productive economy. In both spheres, chemistry plays an essential role. In addition, the nation must be able to deter armed conflict. Again, chemistry is a vital contributor; it enters all areas of defense from propulsion, weapons materials, and classical munitions to the most advanced strategic concepts. (See Section V-C.)

**INTELLECTUAL FRONTIERS IN CHEMISTRY**

Fortunately, this is a time of intellectual ferment in chemistry deriving from our increasing ability to probe and understand the elemental steps of chemical change and, at the same time, to deal with molecular complexity. Powerful instrumental techniques are a crucial dimension. We can anticipate exciting discoveries on a number of frontiers of chemistry.

**Chemical Kinetics**

Over the next three decades, we will see advances in our understanding of chemical kinetics that will match those connected with molecular structures over the last three decades. Lasers by themselves have spectacularly expanded experimental horizons for chemists. They can now probe chemical reactions on a time scale that is short compared to the lifetime of any transient substances that can be said to possess a molecular identity. Elementary reactions can be dissected, first, through detailed control of energy content of reactants and, then, through discrimination of energy distribution and recoil geometry among the products. Pathways for energy movement between and within molecules can now be experimentally tracked and theoretically resolved. These new avenues of study will clarify the factors that govern temporal aspects of chemical change. (See Section III-D.)

**Chemical Theory**

Chemistry is on the verge of a renaissance because of emerging ability to fold experiment and theory together to design chemical structures with properties of choice. With today's computers, accurate calculations can clarify transient situations not readily accessible to experimental measurements, such as intermediate steps in combustion processes. In some cases benefitting from the power of computers, theoretical understandings are developing across chemistry, including dynamics of reactive collisions, electron transfer reactions in solu-



#### **EXECUTIVE SUMMARY**

tion, and statistical mechanical descriptions of the liquid state. (See Section III-D.)

##### **Catalysis**

Developing insights fueled by an array of powerful instrumentation are now moving catalysis from an art to a science. It is now possible to "see" molecules as they react on catalytic surfaces. Metal-organic compounds with purposeful steric specificity and reactivity can be prepared. Organic molecules with predetermined surface conformations that simulate enzymatic architectures can be synthesized. Coherence is appearing that encompasses surface, solution, electrochemical, photochemical, and enzymatic catalysis. Fundamental advances in these various facets of catalysis are forthcoming that will have great economic and technological impact. (See Sections III-A, III-B, V-D.)

##### **Materials**

Modern experimental techniques and chemical principles now permit systematic chemical strategies for discovery and design of novel materials. Hence, chemists are increasingly joining and expanding the specialist communities concerned with glasses, ceramics, polymers, alloys, and refractory materials. Coming years will see entirely new structural materials, liquids with orientational regularity, self-organizing solids, organic and ionic conductors, acentric and refractory materials. Chemists will have a central position on the most dramatic frontier of materials science, the design of molecular-scale memory and electrical circuit devices. (See Sections III-C, V-B, V-D.)

##### **Synthesis**

Modern instrumental techniques greatly facilitate discovery and testing of new reaction pathways and synthetic strategies. Our accelerating progress, which extends from invention of new families of inorganic compounds to the synthesis of ever-more complex organic structures, is erasing the border between inorganic and organic chemistry. Reactivity control in metal-organic molecules can now be achieved through insightful choice of molecular appendages; new soluble catalysts will result. Molecules with metal atom clusters at their cores can be synthesized to link the chemistry of bulk metals to that of simple metal-organic compounds. This linkage relates the action of dissolved and surface catalysts. Organic molecules of biological complexity can be structurally identified and precisely replicated; this opens the way to tailored biological function. (See Sections III-D, IV-A, IV-B, IV-D.)

##### **Life Processes**

The recent striking advances in biology have exposed problems of revolutionary significance that require analysis in terms of molecular interactions. With its ability to deal with molecular complexity, chemistry can play its role in investigating and clarifying the molecular origins of biological processes.



### EXECUTIVE SUMMARY

Working hypotheses for biological functions can be tested through deliberate synthesis of tailored molecules: natural product analogs, chemotherapeutic agents, proteins deliberately altered to provide new functions, genetic inserts. This will move us closer to real understanding of the basic workings of life processes in response to the strongest of human preoccupations, the nature and preservation of life. (See Sections IV-B, IV-C, IV-D, V-B.)

#### Analytical Methods

Conceptual advances in detection, characterization, and quantification of chemical species are benefitting chemistry and contiguous sciences on many fronts. Incorporation of computers is a key factor. Analytical separations based on a variety of chromatographic techniques are essential elements of the rapid progress in identification and synthesis of natural products. Novel ionization methods extend mass spectrometry to biologic macromolecules and other nonvolatile solids. Surface analysis and electroanalytical methods are helping to clarify important aspects of catalysis. Remote spectroscopic and a variety of laser techniques are furnishing timely contributions to environmental monitoring and protection. (See Sections V-A, V-D.)

#### PRIORITY AREAS IN CHEMISTRY (See Ch. VII.)

The strength of American science has been built by allowing creative, working scientists to decide independently where the best prospects lie for acquiring significant new knowledge. Many of the most far-reaching developments, both in concept and application, have come from unexpected directions. Thus, to list priority areas carries the risk of closing off or quenching some adventurous new directions with potential yet to be recognized.

Even so, it makes sense to concentrate some resources in specially promising areas. This can be done if we regard our research support as an investment portfolio designed to achieve maximum gain. A significant part of this investment should be directed toward consensually recognized priority areas but with a flexibility that encourages evolution in these areas as new frontiers emerge. A second substantial element in this portfolio should be support of creative scientists who propose to explore new directions and new ideas. Finally, a third element must be provision of the instrumentation and the infrastructure needed to assure the cost effectiveness of the entire portfolio.

Where this balance will fall for each of the funding sources will vary. Industrial research will weight heavily the currently recognized priority frontiers. At the other extreme, NSF must encourage the new avenues from which tomorrow's priority lists will be drawn. The other mission agencies should structure their portfolios between those extremes. With such a balanced portfolio in mind, the following priority areas are identified with the intent to achieve the greatest intellectual and societal returns.



## EXECUTIVE SUMMARY

### Recommendation 1

Priority should be given to the following research frontiers:

- A. Understanding Chemical Reactivity
- B. Chemical Catalysis
- C. Chemistry of Life Processes
- D. Chemistry Around Us
- E. Chemical Behavior Under Extreme Conditions

Recommendation 1 should be implemented through initiatives sponsored by the relevant mission agencies, scaled by each agency in its own appropriate balance with its support of creative scientists expected to explore new directions and new ideas.

#### *Initiative A. Understanding Chemical Reactivity*

*We propose an initiative to apply the full power of modern instrumental techniques and chemical theory to the clarification of factors that control the rates of reaction and to the development of new synthetic pathways for chemical change.*

Principal objectives are to sustain international leadership for the United States at the major fundamental frontier of chemistry—control of the rates of chemical reactions—and to provide the basis for U.S. competitive advantage in development of new processes, new substances, and new materials.

#### *Initiative B. Chemical Catalysis*

*We propose an initiative to apply the techniques of chemistry to obtain a molecular-level and coherent understanding of catalysis that encompasses heterogeneous, homogeneous, photo-, electro-, and artificial enzyme catalysis.*

A principal objective here will be to provide the fundamental knowledge and creative manpower required for the United States to maintain competitive advantage in and to develop new catalysis-aided technologies.

#### *Initiative C. Chemistry of Life Processes*

*We propose an initiative to develop and apply the techniques of chemistry to the solution of molecular-level problems in life processes and to develop young research scientists broadly competent in both chemistry and the biological sciences.*

A principal objective of this initiative will be to accelerate the conversion of qualitative biological information into techniques and substances useful in biotechnologies, in human and animal medicine, and in agriculture.

#### *Initiative D. Chemistry Around Us*

*We propose an initiative devoted to understanding the chemical make-up of our environment and the complex chemical processes that couple the atmosphere,*





### EXECUTIVE SUMMARY

*oceans, earth, and biosphere, with special reference to man's conscious and inadvertent disturbance of this global reactor. Analytical chemistry and reaction dynamics define the core of this initiative.*

Principal objectives of this initiative are to provide the basic chemical understandings needed to protect our environment and to extend detection of potentially hazardous substances well below toxicity bounds so that potential problems can be anticipated and ameliorated long before hazard levels are reached.

#### *Initiative E. Chemical Behavior Under Extreme Conditions*

*We propose an initiative to explore chemical reactions under conditions far removed from normal ambient conditions. Chemical behaviors under extreme pressures, extreme temperatures, in gaseous "plasmas," and at temperatures near absolute zero provide critical tests of our basic understandings of chemical reactions and new routes toward discovery of new materials and new devices.*

Principal objectives are to broaden our understanding of chemical change and to lead to new materials that will have application under extreme conditions of pressure, temperature, and exposure to specially challenging environments (e.g., fusion reactors, reentry vehicle heat shields, superconducting magnets).

### EXPLOITING THE OPPORTUNITIES IN CHEMISTRY

The extent to which our nation will be able to benefit directly from these promising frontiers in chemistry is, in part, a matter of resources. This report shows that existing patterns of funding are anachronistic and inadequate. Average grant sizes are too small; for example, the average NSF grant will barely support the research activities of two or three students, while an active research group might range in size from six to sixteen (see Table VII-8 and the discussion preceding it). Furthermore, the grants do not provide support for the infrastructure needed to sustain the sophisticated scientific activities of today's chemistry (electronic, computer, and laboratory technicians, machinists and glass blowers, supplies). The inadequacy of support for "mid-cost" instrumentation (less than \$1 million), both for shared use among several research groups and for specialized and dedicated use, requires painful trade-offs that tend to restrict capacity to fund new, young investigators entering chemistry. (See Figure, p. 302.) The instrumentation crisis is exacerbated because university chemistry departments are struggling to provide the operating and maintenance infrastructure needed to use this state-of-the-art equipment with maximum cost effectiveness. (See Tables VII-4 and VII-6.)

The listing of opportunities and potential rewards to society that will flow from them is impressive. That we cannot afford to lose these rewards is underscored by the economic importance of chemistry. Business and industry employ more doctoral chemists than the sum of those employed in the biological



#### **EXECUTIVE SUMMARY**

sciences, mathematics, physics, and astronomy combined (see Appendix Table A-4). Yet we find that the average federal investment in the crucial human resource in chemistry is only one fifth as much per Ph.D. as in other comparably important disciplines (see Table VII-1). Without a more determined U.S. commitment to the chemical sciences, there is substantial likelihood that our leadership position will be preempted abroad.

#### **Chemistry in Industry**

The Chemistry and Allied Products industry invests heavily in its own in-house research. This report should be of value to the industry as it decides upon the amount and focus of its own research investment. In addition, U.S. industry has an interest in the health and direction of university-based fundamental research. Industrial progress and competitiveness also depend upon access to a reservoir of fundamental knowledge constantly replenished by university-based research and upon a stream of talented young scientists familiar with the latest chemical frontiers and instrumental techniques. Hence, industry furnishes direct support to university research. Though modest in total (about \$10 million each to chemistry and chemical engineering in 1983), it is extremely important because it facilitates movement of new discoveries into new applications and influences university research agendas.

#### **Recommendation 2**

**New mechanisms and new incentives should be sought for strengthening links between industrial and academic research.**

#### **Recommendation 3**

**Industry should increase its support for university fundamental research in the chemical sciences. Tax incentives to encourage such gains should be explored.**

#### **The Federal Role in Fundamental Research**

Industry can engage in only a modest amount of the most fundamental and adventurous research because the time horizon for application is remote. Yet, this "high-risk" research offers the most far reaching benefits to society and the intellectual basis for technological competitiveness. It is an appropriate place for public investment.

This report displays an array of opening research frontiers rich in potential for societal benefit. In this setting, an examination of funding patterns in a variety of disciplines that depend upon sophisticated instrumentation reveals that the federal investment in chemistry is not adequate and will not bring to society the full benefits to be realized.

*EXECUTIVE SUMMARY*

**Recommendation 1**

The federal investment in chemistry should be raised to be commensurate with the practical importance of chemistry, both economic and societal, and with the outstanding intellectual opportunities it now offers.

**Chemistry and the NSF Mission**

Chemistry supported by the NSF is judged on its potential for adding to our understanding of nature. Since the most far-reaching technological changes tend to stem from unpredictable discoveries, the fundamental research supported by NSF is critical to this country's long-range technological future. The increasing dependence of our economy upon the health of our chemical industry coupled with the exciting intellectual opportunities in chemistry justify a considerably larger NSF support in all three of its crucial dimensions: shared instrumentation, dedicated instrumentation, and grant size. Such support is needed to assure a U.S. position of international leadership in the exploitation of the rich opportunities before us.

**Recommendation 5**

(a) NSF should begin a 3-year initiative to increase its support for chemistry by 25 percent per year for FY 1987, FY 1988, and FY 1989.

(b) The added increments should be directed toward increasing grant size, ensuring encouragement of young investigators, enhancing the shared instrumentation program, and increasing the amount directed toward dedicated instrumentation.

(c) NSF should build into its shared instrumentation program a federal capital investment averaging at 80 percent of instrument cost together with maintenance and operating costs for a 5-year period after purchase.

**Chemistry and the Department of Energy Mission**

For at least the next quarter century, 90 percent of our still growing energy use must come from chemical energy sources. At the same time, the quality and character of feedstocks will be changing in ways that challenge existing technologies and that make it harder to resolve society's concerns about environmental pollution. To meet these challenges, the Department of Energy currently invests in its Chemical Sciences Program only 5 percent and in its Biological Energy Research Program less than 1 percent of the total resources it directs toward 11 of its largest fundamental research programs. To assure our future access to abundant and clean sources of energy over the next three



#### **EXECUTIVE SUMMARY**

decades, DOE must make a much larger commitment to the chemical sciences. This commitment must engage more fully both the DOE National Laboratories and the larger chemistry community.

#### **Recommendation 6**

(a) The DOE should establish a major initiative in those areas of chemistry relevant to the energy technologies of the future.

(b) In an appropriate number of our National Laboratories, the defined mission should be reshaped to include a major focus on one or more of the chemistry areas crucial to energy technologies.

(c) University research programs in energy-relevant areas of chemistry should be raised to be commensurate with those in the National Laboratories.

(d) Incremental growth in these programs by a factor of about 2.5 will be needed to exploit the opportunities before them. For cost effectiveness, this growth should be uniformly spread over the next 5 years. A \$22 million incremental growth in the FY 1986 DOE chemistry budget would support an appropriate beginning.

#### **Chemistry and the NIH Mission**

Progress in both medicine and chemistry now makes it possible to interpret complex biological events at the molecular level. Because of the ubiquitous role of chemistry in human health, NIH provides substantial support to chemists engaged in research at the broad interface of physiology/medicine/chemistry. Chemistry research relevant to the NIH mission concentrates largely in the Institute for General Medicinal Sciences. Characteristically, the grants are modest in size, and the award success rates have fluctuated widely over the last decade.

#### **Recommendation 7**

(a) A fraction of any additional NIH funds in support of chemistry should be used to increase average grant size, including grants for young investigators and particularly for cross-disciplinary collaborative programs that link expertise in chemistry with that in other health-science disciplines.

(b) NIH should vigorously continue its attempts to stabilize its extramural grant program.

(c) NIH should maintain its extramural shared instrumentation program at a level approximately equal to that of NSF. The initial federal capital investment should include at least 80 percent of instrument cost, and maintenance and operating costs should be provided for 5 years after purchase.

**EXECUTIVE SUMMARY****Chemistry and the Department of Defense Mission**

Chemistry plays a critical part in our national security. It not only strengthens our ability to deter and prevent armed conflict, it also contributes strongly to the health of the economy and to the maintenance of the technical manpower pool needed to develop and deploy our increasingly sophisticated defense technologies. In the longer view, our future national security, our international economic posture, and our technical manpower supply dictate DOD attention to fundamental chemical research, including that conducted at universities. Yet DOD support of fundamental research has grown very little over the last 5 years; its investment in university research does not fulfill DOD's desire to maintain our manpower pool while providing indirect influence on university research agendas toward promising chemistry areas key to our defense posture.

**Recommendation 8**

(a) The percentage of the DOD R&D budget directed to basic (6.1) research should be increased to restore the 1965 value of 5 percent.

(b) DOD support for university research in the chemical sciences should be raised to about 25 percent of the total federal support for basic research through real growth at 10 percent per year.

(c) Parallel growth should be provided to DOD in-house research programs of the 6.1 category in chemistry.

(d) Growth should concentrate attention on the special opportunities now offered through chemistry in the following broad research areas:

- Strategic and critical materials
- Fuels, propellants, and explosives
- Atmospheric phenomena
- Chemical and biological defense
- Nuclear power and nuclear weapons effects

(e) Interaction between DOD laboratories and universities should be encouraged and increased.

(f) DOD should continue its instrumentation program but with the addition of support for maintenance and operation.

(g) DOD should explore mechanisms to support new construction and renovation of university research facilities in particularly critical areas of chemistry.

## **EXECUTIVE SUMMARY**

### **Chemistry and the Department of Agriculture Mission**

The USDA devotes only a small portion of its R&D budget to chemistry research relevant to agriculture and animal health. But human needs are great, so we can ill afford to miss the relevant opportunities offered by chemistry.

#### **Recommendation 9**

The Department of Agriculture should initiate a substantial competitive grants program in chemistry with the aim of increasing extramural support of fundamental research in chemistry relevant to agriculture and animal health to an approximate par with the Department's intramural program.

### **Chemistry and the National Aeronautics and Space Administration Mission**

The several initiatives proposed in this report present opportunities for improvement of the safety, range, and effectiveness of future space operations. Furthermore, NASA has unique capabilities for monitoring and mission-related concern about the changing chemical compositions of the troposphere and the stratosphere.

#### **Recommendation 10**

(a) The National Aeronautics and Space Administration should maintain a substantial commitment to the understanding of atmospheric chemistry.

(b) Increased attention should be directed toward special opportunities relevant to operations in space:

- high energy propellants
- chemical behavior under extreme conditions
- reaction kinetics and photochemistry under collision-free conditions
- chemical aspects of life-sustenance in a closed system
- analytical methods for compositional monitoring in both the troposphere and the stratosphere

(c) NASA should more actively encourage academic chemists to address problems relevant to the NASA mission through competitive grants for fundamental research.

**EXECUTIVE SUMMARY****Chemistry in the Environmental Protection Agency**

The EPA has significant R&D programs specifically and properly directed toward currently recognized environmental problems, and many of these programs involve chemistry. This agency assumes a much less active role in fundamental research relevant to its mission as epitomized by its tiny Exploratory Research program. This extramural program is now funded at \$16M, less than 0.4 percent of the \$4.25B EPA total. The EPA should follow the pattern of other federal mission agencies by defining those areas of research that underlie its mission goals and stimulating the expansion of knowledge in those areas through programs of fundamental research.

**Recommendation 11**

(a) EPA should increase the percentage of its R&D funds placed in its Exploratory Research program and its commitment to extramural fundamental research relevant to environmental problems of the future.

(b) EPA should encourage fundamental chemical research to clarify reaction pathways open to molecules, atoms, and ions of environmental interest.

(c) EPA should take a prominent role in support of long-range research in analytical chemistry with emphasis on extension of sensitivity limits, increase in detection selectivity, and exploration of new concepts.

(d) EPA should have as a conscious and publicized goal the detection of potentially undesired environmental constituents at concentration levels far below known or expected toxicity limits.

**Conclusion**

In the next two decades there will be dramatic changes in our basic understanding of chemical change and in our ability to marshal that understanding to accomplish deliberate purpose. The program presented here defines a leadership role for the United States as these advances are achieved. The rewards accompanying such leadership are commensurate with the prominent role of chemistry in addressing society's needs, in ameliorating problems of our technological age, and in sustaining our economic well-being. The costs of falling behind are not tolerable.



COMMENTS BY JOHN D. REHNBERG  
Vice President, The Perkin Elmer Corporation  
Space Station Workshop, Nashville, TN  
November 3-5, 1987

## INTRODUCTION

Good morning, ladies and gentlemen. It is a pleasure to represent The Perkin Elmer Corporation and the Analytical Instrument Industry at this Space Station Workshop.

## POST APOLLO ERA

Before I discuss the specific needs of my industry segment, I would like to briefly summarize some of the driving technological innovations that can be attributed to the early Space Program of the 60's and the resultant impact these technologies have had on instrument developments in the 70's and 80's.

One example I like to use is the application of the mass spectrograph as an instrument to monitor the cabin atmosphere of early space modules. These instruments were perfected for use in space, then later, militarized versions were developed for the U.S. Navy for application in nuclear submarines in the early 70's, and then commercial versions for use in industrial and medical environments. Mass spectroscopy has proven to be a core technology in a number of instrument businesses.

The post-Apollo era brought on significant developments in infra-red detectors, solid station diodes and arrays, micro-electronics and materials technology.

The instrument industry has made successful use of this technology revolution by developing instruments that today give orders of magnitude of information and data processing at a fraction of the previous cost and in a fraction of the time.

The use of CCD arrays, echelle gratings, VLSI and imbedded software have allowed us to build sophisticated instruments with built-in data processors. Significantly improving the scientist's productivity.

## WHAT CAN THE SPACE STATION DO FOR THE INSTRUMENT INDUSTRY?

The 1970's and early 80's brought on a revolution in micro-electronics, computers and material technologies. These advances are being incorporated into the instruments that are currently reaching the marketplace.

If one tries to imagine what the needs will be 15 years from now and how the Space Station might have a direct impact, I believe history will prove to be an acceptable guide for such an extrapolation.





The instrument business is really an integral part of the information processing business. The scientist must order data from an N-dimensional set of phenomena involving space, time, species and physical properties. The better one can instantaneously sample all these parameters, process the data and make decisions based on the data the more productive he can be in his scientific endeavors.

Let us now allow our imagination to wander from the present knowns to the expected extension of these knowns.

- In the field of detectors, we can expect to have large area CCD arrays that can be sensitive in the UV, visible and IR.
- Superconductivity developments should yield high temperature detector materials that will allow the use of detector noise limited systems closer to room temperature operation.
- Material technology in stable composites and ceramics will change our approaches to instrument packaging and manufacture.
- Data processing sub-systems will make use of VLSI and new computer architecture. "Expert" system applications to the processing of instrument data will be a very fertile field.
- Continued developments in the field of mass spectroscopy will yield benefits in the field of chromatography as well as other application areas.
- Incorporation of microelectric technology with transducer improvements could yield integrated microsensors which would be invaluable in biological and chemical sensing.

I have only scratched at the surface of some specific areas where I can foresee a payoff. What, we can not see are those developments that will take place during the next 10 years which will further advance the information processing revolution.

POST APOLLO ERA

- MASS SPECTROSCOPY
  - ATMOSPHERIC MONITORS
  - MILITARY, INDUSTRIAL AND MEDICAL APPLICATIONS
- DETECTOR TECHNOLOGY
- MICRO ELECTRONICS
- MATERIAL AND MANUFACTURING TECHNOLOGY
- INSTRUMENT EXPLOITATION USING CCD, VLSI, IMBEDDED SOFTWARE AND COMPOSITE MATERIALS

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**PERKIN ELMER**

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POST SPACE STATION ERA

- TECHNOLOGY DEVELOPMENTS
  - DETECTORS
  - MATERIALS
  - SUPERCONDUCTIVITY
  - VLSI AND SUPER MICRO COMPUTERS
- DATA PROCESSING ADVANCES
  - TIME, SPACE, SPECIE (N-DIMENSIONAL PRESENTATION)
  - EXPLOITATION OF VLSI AND SUPER MICRO COMPUTERS
  - PERFECT APPLICATION FOR "EXPERT SYSTEMS"
- DETECTORS
  - HIGH TEMPERATURE SUPER CONDUCTIVE DEVICES
  - LARGE AREA CCD ARRAYS
  - DETECTOR NOISE LIMITED DEVICES @ ROOM TEMPERATURE
- MATERIALS
  - MICRO PRECISION AND MACHINING
  - DIMENSIONALLY STABLE
  - THERMALLY INSENSITIVE
- INTEGRATED DEVICES
  - MICROSENSORS FOR BIOLOGICAL CHEMICAL SENSING

TECHNICAL CHALLENGES FACING CUMMINS ENGINE COMPANY  
OVER THE NEXT FIFTEEN YEARS

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## TECHNICAL CHALLENGES FACING CUMMINS ENGINE COMPANY OVER THE NEXT FIFTEEN YEARS

### I. BACKGROUND - CUMMINS ENGINE COMPANY

Cummins Engine Company is a leading worldwide designer and manufacturer of in-line and V-type diesel engines ranging from 55 to 1800 horsepower. In addition, Cummins produces and markets a broad range of engine-related components, power systems and services worldwide.

The Company's principal market is the North American heavy-duty truck industry, with every major North American truck manufacturer offering Cummins engines as standard or optional equipment. Cummins presently holds a 57-percent share of this market. Major off-highway customers are construction, mining, agricultural and other industrial equipment manufacturers.

Components produced include crankshafts, turbochargers, filters and piston rings, as well as remanufactured engines and parts. Power systems offered by Cummins include heat transfer equipment, transmissions, electronic control systems and electric generator sets. Services include computer software for automotive dealers, computerized operating information for fleets and financial services. Electronic cash transfers, permits, engine diagnostics, driver training and road services are provided for truckers. Service products include lubricating oil, tools and truck heaters.

Cummins fits in the middle segment of U.S. industry. Cummins purchases raw forms, such as steel barstock, castings, and forgings, and does the rough machining, heat treatment, and finish machining to generate the components' critical characteristics. The components made in-house and those bought finished, such as sleeve bearings and bushings, are subsequently assembled into an engine which is shipped to an original equipment manufacturer (OEM). The equipment is then sold to an end-user - the customer. It is important to understand this because it will put primary focus on some technologies and relegate others to a secondary role.

## II. SUMMARY OF TECHNICAL CHALLENGES

The technical challenges that will be discussed are as follows:

Meeting 1991 and 1994 emissions regulations.

Increase fuel economy.

Develop alternate fuel capability.

Increase power density.

Increase durability.

Remain cost competitive in a worldwide marketplace.

## III. MEETING 1991 AND 1994 EMISSIONS REGULATIONS

The following table summarizes the EPA heavy-duty diesel engine emissions regulations:

### EPA HEAVY-DUTY DIESEL EMISSIONS REGULATIONS

<u>EMISSIONS (G/BHP-HR)</u>	<u>1988</u>	<u>1990</u>	<u>1991</u>	<u>1994</u>
HYDROCARBONS	1.3	1.3	1.3	1.3
OXIDES OF NITROGEN	10.7	6.0	5.0	5.0
PARTICULATES	0.6	0.6	0.25 (0.10 BUS)	0.10

The reduction in particulates is the technical challenge that confronts our industry. Cummins is currently marketing engines which meet the 1990 regulations. The significant challenge is to meet the 1994 standards without the use of regenerative particulate traps in the exhaust gas stream. Such a trap would increase the cost of an engine and has the potential of degrading performance. An in-cylinder solution to this problem will result in a significant advantage in the marketplace.

It is expected that an in-cylinder solution will require the following:

- Thinner oil films between in-cylinder components (less lubrication available).
- Higher surface temperatures of the in-cylinder components.

- Higher fuel injection pressures which increase the energy of mixing fuel and air.
- Clean burning lubricant base stocks.

Current work on experimental engines, designed to meet 1994 emissions standards, estimates that 40 percent of the exhaust particulates are derived from the lubricant. Any increase in the lubricant contribution is clearly undesirable. Therefore, future engines will require thinner oil films between the piston ring, piston, and cylinder liner. To control particulates, there will be less lubrication available for in-cylinder components which will also operate at higher surface temperatures. The current system of cast iron liners, aluminum pistons, chrome-plated ductile iron piston rings, and petroleum-based lubricants will no longer be adequate.

A new cost-effective material system of in-cylinder components will have to be developed. Such a material system will consist of the following:

- Insulating ceramic coatings which are reliable, durable, and reproducible.
- High temperature, wear resistant surfaces on piston rings with thermally stable substrates.
- High temperature, light-weight, fatigue resistant piston materials.
- Clean burning, thermally stable liquid lubricants.

The technical challenge is to translate these requirements into cost-effective designs.

#### IV. FUEL ECONOMY

The success of the diesel engine as a source of mobile, land-based power has been the result of its efficient use of fuels. As far as fuel economy is concerned, it is better than gas turbines and gasoline-fired engines. The heavy-duty segment of on-highway transportation has long been 100 percent diesel powered. As a consequence of fuel economy, dieselization is progressing into smaller vehicles as shown in the following table:

### DIESELIZATION RATE OF ON-HIGHWAY VEHICLES

	<u>ACTUAL</u>			<u>FORECAST</u>
	<u>1973</u>	<u>1983</u>	<u>1984</u>	<u>1990</u>
Light Commercial	0%	18%	22%	43%
Mid-Range	10%	56%	60%	76%
Heavy-Duty	100%	100%	100%	100%

The improvement in fuel economy of heavy-duty diesel engines has a long history, and this trend will clearly continue because it is a continued requirement specified by the customer.

### TREND FOR HEAVY-DUTY FUEL CONSUMPTION

	<u>1940</u>	<u>1950</u>	<u>1960</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>
Engine BSFC (Lbs/Hp-Hr)	0.55	0.45	0.40	0.40	0.33	0.27-0.33*

\*Estimate in 1990 is due to emissions uncertainty.

If fuel costs increase due to global economic forces, then the incentive to improve fuel economy will increase dramatically.

It is expected that fuel economy gains will be achieved by the following:

- Design of high injection fuel systems.
- Optimized design of turbochargers.
- Application of ceramic materials to insulate components in the combustion chamber and in the exhaust gas path.
- Design and application of an efficient waste heat recovery device.
- Minimizing parasitic losses in the engine system.

All of the listed approaches represent substantial technical challenges in designing hardware that will operate successfully in a fuel efficient engine. For example, the fuel injection pressure is produced by a unit injector which is actuated by an engine camshaft, a roller tappet assembly, and a mechanical injector train. The rolling contact stress at the cam-roller interface is directly related to the injection pressure. As injection pressures increase so do the rolling contact stresses. The current rolling contact stress design limit of the engine

camshaft is 240,000 psi, and it is expected to have to increase to 300,000 psi.

Friction and parasitic losses within an engine can account for 6 percent of the available fuel energy at rated power. The primary contributors to these losses are the piston and piston rings, lube and water pump, valve and injector trains, air compressor, main and rod bearings, cam and gear train. Intake and exhaust restrictions are also usually considered to be parasitic losses, even though not mechanical. Mechanical frictional losses comprise about 50 percent of the total parasitic losses. The total efficiency of a turbocharged, aftercooled diesel engine is currently about 40 percent based on fuel energy. Therefore, the total potential improvement in fuel economy from eliminating all frictional losses is 7.5 percent (at rated power). It is unrealistic to expect complete elimination of all frictional losses. A reduction by 50 percent may be feasible. This yields a 4 percent fuel economy improvement potential at rated. Since the frictional losses are not highly sensitive to load, improvements in part load fuel economy by reducing friction can be much higher.

The piston skirt and ring contact with the liner accounts for approximately 60 percent of mechanical engine friction. The conventional, oil lubricated piston ring design is constrained by two opposing requirements. Friction and wear must be minimized by maintaining a reasonable oil film between the rings, piston and liner. Oil consumption, however, must be controlled by minimizing the oil film on the liner. These two constraints define an optimization problem.

## V. ALTERNATE FUELS

Meeting stringent emissions regulations has been mentioned as a technical challenge. The oxides of nitrogen (NOx) and particulate emissions follow a classic hyperbolic relationship when an engine is run on diesel fuel. In other words, when the engine operating conditions are set to result in low particulates, a high NOx level occurs and at conditions for low NOx, high particulate concentrations occur in the exhaust gas stream. Significant progress has been made in shifting this relationship to emit lower particulates at a given NOx level. As lower particulate emissions are achieved, the contribution by combusting the lubricating oil film and contaminants in the fuel becomes a significant portion of the particulates in the exhaust gas stream. In order to meet EPA requirements of 0.1 gm/HP-Hr particulates (including deterioration factor, production tolerance variability, selective enforcement, etc.), the design target has to be lower than 0.1 gm/HP-Hr.



It is a possibility that this may not be feasible with diesel fuel unless a particulate trap is used. Alternate fuels may offer an opportunity to meet emissions requirements without adding an expensive, regenerative particulate trap.

There are a variety of alternate fuels, such as methanol and natural gas, which exhibit emissions characteristics attractive for use in heavy-duty diesel engines.

Natural gas can be described as primary fuel and is not tied to petroleum base. Methanol can be derived from various feed stocks including natural gas, coal and biomass. Major production of methanol currently uses natural gas as the feed stock and its current oversupply is due to the abundance of this resource material.

Various characteristics of methanol and natural gas fuels compared with diesel fuel are shown in the following table:

#### FUEL CHARACTERISTICS

<u>FUEL CHARACTERISTICS</u>	<u>DIESEL</u>	<u>METHANOL</u>	<u>NATURAL GAS</u>
Energy Density	1	.5	.35 CNG .65 LNG
Combustion Eff.	1	1	.83
Safety	1	<1	≈1
- Visibility			
- Dispersion			
Toxicity	1	<1	1
Infrastructure	1	<1	<1
Diesel Equivalent	1		
Better Than Diesel	>1		
Worse Than Diesel	<1		

The qualitative comparison uses an indicator of 1 if the parameter is similar to diesel; >1 if the parameter is better than diesel and <1 if it is inferior to diesel. The table highlights differences in alternative fuel characteristics with respect to diesel fuel. Prototype methanol fuel engines exhibit similar thermal efficiency to diesel fueled engines, and since it is a liquid fuel, the issue of energy density is overcome by greater refueling frequency or bigger fuel tanks. However, a user acceptance of methanol is yet to be resolved in view of the known concerns with safety, toxicity and fuel infrastructure. Natural gas has major issue with its energy/density/

refueling parameters and current developments indicate that the thermal efficiencies are less than diesel fuel.

A perspective of engine technologies is presented in the following table:

CURRENT ENGINE TECHNOLOGY PERSPECTIVE

<u>CHARACTERISTICS</u>	<u>DIESEL</u>	<u>METHANOL</u>	<u>NATURAL GAS</u>
Reliability - Unscheduled Down Time	Excellent	?	High
Durability - Life to Overhaul	Long	?	?
Specific Output	High	High	Mid
Fuel Economy	High	High	Mid
Cost	Low	High	High
Emissions			
- NOx	Mid-Low	Low	High
- Part	Mid	Low	Low
- Aldehydes	Low	High	Low

The major issue with diesel engines is exhaust particulates. Methanol engines present the added issue of aldehydes in the exhaust. The reliability and durability of methanol-fueled engines is yet unknown. It is anticipated that these engines will be higher in cost compared to current diesel engines. Natural gas fired engines generate low particulates but cause high NOx levels. These engines also have inferior fuel consumption, specific output, and higher cost compared to a modern diesel engine. To gain wide customer acceptance, engines fired with alternate fuels will need to achieve reliability, durability and cost standards equivalent to diesel fired engines. Here lies the technical challenge. (The above discussion is extracted from a paper to be published by Vinod Duggal, Cummins Engine Company.)

VI. POWER DENSITY

One of the driving forces within U.S. industry is "to do more with less." Mechanical systems clearly have an ultimate limit to this axiom. Increasing the power output for a specific engine design has always been a technical challenge for the engineering work force. The customer demands it and expects it, and increasing the power

output of a given engine design prolongs the life of the engine product line. For example, our current in-line six-cylinder, 855 cubic inch displacement engine was originally designed to yield 250 horsepower in the naturally aspirated condition. It currently is marketed with a 444 horsepower rating which is turbocharged and aftercooled, and it is being experimentally tested at 500 horsepower. A 600 horsepower rating is being planned.

Uprating engine families has always presented technical challenges to designers, materials experts and stress analysts. Uprating an engine typically increases stresses, temperatures, and wear rates and the design criteria for reliability, durability, and serviceability are never relaxed.

## VII. DURABILITY

The term reliability and durability are frequently used synonymously. At Cummins, we have tried to define them separately. Reliability refers to failure events that occur within the first 100,000 miles, and these events are typically covered under standard warranty. Reliability is expressed or quantified in terms of number of repairs per hundred engines produced. In contrast, durability refers to longer term events, beyond the warranty period, which cause an engine to be rebuilt or overhauled. Durability is quantified in terms of miles to first overhaul. Engine families are tracked in terms of B10 lives, average miles or hours to first rebuild.

Since 1967, the durability of the Cummins heavy-duty diesel engine has increased by a factor of four. The marketplace is continually requesting improvements in durability because it is a maintenance cost which is typically paid by the customer. It has been stated that an increase of 100,000 miles in durability can decrease the total operating cost to the end-user by \$6,000 to \$10,000. There will continue to be an emphasis on improving engine durability.

Since it is a long term problem, the technical challenges are many and they are frequently not clearly defined. Some of the technical issues are as follows:

- Improved lubricating oil quality.
- Understanding and applying tribological principles in the design stage.
- Air and oil filtration.

- Engine coolant maintenance and filtration.
- Designing with wear resistant ceramic materials and coatings.
- Full understanding and complete control of the design and manufacture of the in-cylinder components.
- Designing and developing gaskets and seals for long term engine operation.

#### VIII. SUMMARY

As evidenced by the previous discussion, none of these technical challenges are mutually exclusive. In addition, cost weaves its own emphasis throughout the technical arena. Technical problems cannot be solved to the exclusion of total life cycle cost. The most cost-effective design, material, and manufacturing processes will yield the ultimate solution to these technical challenges. This is the only way U.S. industry can stay competitive in the worldwide marketplace.

"We expect our future environment to set strict minimum standards for engine acceptance in the marketplace. Key areas of concern will be first cost, durability, reliability, serviceability, horsepower and performance improvements, and emissions control (NOx particulates, smoke, noise) within regulated limits. If engines meet these market acceptance criteria, then fuel consumption is likely to be the most active area of competition. Our response to the markets of the future, therefore, will be to drive technology in the direction of superior fuel economy, higher specific output, lower emissions, more horsepower and torque rise, easier maintenance, longer life, and lower first cost. All of this, of course, must be accomplished simultaneously, since we are managing a very complex system whose elements are synergistically related. Fuel economy improvements are relatively easy to achieve, for example, if emissions, durability, and power density standards are relaxed. It follows that fuel economy gains of the past could very easily be lost in efforts to meet more stringent standards for emissions, durability, and power density." (James W. Patten, Executive Director - Material Engineering, Cummins Engine Company.)

## TRANSPORTATION EQUIPMENT INDUSTRY TECHNOLOGY NEEDS

SPACE STATION WORKSHOP

3-5 NOVEMBER 1987

Dr. Edward Trachman  
Director of R&D  
Rockwell Automotive Operations

### Products

- Axles
- Brakes
- Drivelines
- Suspension Components
- Mechanical Devices
- Plastic Components
- Transmissions
- Electronics

### Components

- Gearing
- Shafts
- Spindles
- Brackets
- Hubs
- Drums
- Housings
- Springs
- Latches

#### Procurement Commodities

- Steel
- Forgings
- Stampings
- Castings
- Bearings
- Brake Linings
- Fasteners
- Seals
- Gaskets
- Bushings
- Screw Machine Parts
- Purchased Complete Parts

#### Materials

- Plain Carbon Steel
- Low Alloy Steel
- Cast Irons
- Cast Steel
- Non-Ferrous (modest amount)
- Plastics (RIM)
- Friction Materials

#### Comments

- High volume, low value added products
- Little involvement in materials production

## **Goal**

Gain understanding from space-based research  
leading to new, low-cost structural materials.

## **Unique Features of Space Processing**

- Zero gravity
- High vacuum

### **Possible Interests**

- Directional properties/solidification
- Immiscible alloys
- Isothermal solidification

Materials and Technology  
for the Electric Power Industry

S. Yin and M. R. Hall  
Yin Research Corp., Square D. Company

The following viewpoint selects and highlights some of the current activities of the electric power industry. It is not intended to be comprehensive, but to provide a brief overview of the most advanced and promising materials and techniques in relation to the needs of the industry. It is also an attempt to foresee future needs and developments.

Power distribution and power generation have been chosen as the basic categories for discussion. Power generation further subdivides into the various technologies based on energy sources. These include power generation using organic fuels such as coal, oil, gas and sometimes waste materials; also those that use the energy of flowing water, winds or waves; those that use nuclear fuels, fission and eventually fusion; those that use direct solar energy, either in a thermal cycle or in photovoltaic devices and also, perhaps, magnetohydrodynamic (MHD) generators and cogeneration schemes. Only a little attention is given here to the special needs of the nuclear power industry, except to note the need for radiation-resistant materials and the waste management problem. MHD and nuclear fusion technologies are also passed over lightly, in order to keep the presentation and discussion short.

The major problems in power distribution are connected with the need to use higher voltages and current-carrying capacities for greater efficiency and also to meet increasing consumer demand. This places greater demands on the service properties of materials and calls for increased device ratings: transformers, switches and circuit protective devices. It also increases the difficulties of fault detection and transient measurement.

The need for higher thermal efficiencies in power generation continues to increase the service temperatures of metals, alloys and advanced ceramics. The low T superconductive metals can be used to improve generator efficiency and to reduce size and weight. New materials for high temperature batteries and for fuel cells have emerged as alternative electric energy storage devices to help meet peak load demands. Microprocessor-based systems provide better control in many aspects of power generation and distribution. Better emissions control and waste management will continue to be needed to maintain ecological balance and to provide for health and environmental quality. These problems and solutions are especially relevant and urgent for manned space stations and for explorations to the moon and planets.

Currently the electric power industry is associated with sectors of industry that are more directly involved in space-related activities. Electric power sources, equipment and services are essential to the ground-based efforts in all sectors of the economy that supply, serve or directly use the facilities that are currently devoted to space work. The industry benefits directly from increased sales, from gains in technology and the increased numbers of trained scientists, engineers and technicians. Figure 1 lists the benefits in several



categories. There are direct benefits to the industry of an economic, scientific and technological nature. Indirect benefits to the industry are more or less identical with the economic, scientific, technological, sociological and political benefits that are rendered to the nation and to mankind.

At this time, see Figure 2, the industry benefits from advances in electronics that include various solid state devices, microprocessor controls, and opto-electronics and from advances in materials and processes that have produced better insulators from advanced ceramics, polymers and polymer-ceramic composites; solid-state protective devices, sensors and fiber optics; high temperature alloys to resist corrosion, erosion, wear, radiation and hydrogen embrittlement; improved contact materials for switches and circuit breakers; amorphous metals and superconducting alloys and compounds that can be used to produce more efficient transformers, generators and motors; new materials for batteries and fuel cells and improved catalysts, substrates and filter media. In many cases the development of these new devices, materials and processes has originated in programs directly connected with the nation's space effort. In many other cases development has been accelerated and sustained, at least in part, by an actual or potential value to space-related needs.

It seems likely that the future will bring about solar power satellites or power transmissions to and/or from orbiting stations and the earth. These developments would involve the electric power industry in a more direct way with space activities, especially in the tie-in to earth-based power generation and distribution systems. There seems to be a strong possibility that the development of new semiconducting materials may lead to solid-state switches and circuit breakers which could replace at least some of the mechanically operated contact types now in service. Superconductors that operate near ambient temperature will be likely to bring about major improvements in generators, motors, transformers, magnetic storage systems and, perhaps, high voltage transmission lines. There will continue to be a need for stronger and better low-loss, high dielectric strength ceramics and polymer-ceramic composites for insulators, see Figure 3. Superconductive sensors may be exploited as current and voltage detectors in fault detection and transient measurements. Opto-electronic and photonic devices linked with faster microprocessors will be useful for remote sensing and control. Improved high temperature materials will continue to be sought to increase the operating temperatures of turbines, and for fission reactors and new kinds of fusion machines. More efficient and lower cost solar cells will be needed and light weight solar collectors that can be placed in orbit will need improved optical and structural materials. A new generation of microwave and optical lasers may serve for transmission of power to and from space. Materials for environmental protection and emission control will continue to be very important.

Everything that has been mentioned up to this point is already on the horizon for future development. The rapidly increasing pace of scientific development leads us to expect many more exciting and useful discoveries and developments just over the horizon. Perhaps in these discussions we will be able to get some ideas that will help to see just a little farther and to stimulate some new lines of research.

FIG. 2. CURRENT STATUS: MATERIALS AND TECHNOLOGICAL NEEDS				
	METALS	CERAMICS	SEMICONDUCTORS	COMPOSITES
POWER DISTRIBUTION (EHV AND UHV)				
CONDUCTORS	SUPERCOND. NbTi	GLASS-CERAMIC OTHER ADV. CER.		POLYMER- CERAMIC
INSULATORS				
TRANSFORMERS	AMORPHOUS METALS			
CIRCUIT PROTECTION	CONTACT MATERIALS.		VARISTERS. ZENER DIODES. MICROPROC.	
FAULT DETECTION & TRANSIENT MEASUREMENT		FIBER OPTICS	SENSORS. MICROPROC.	
POWER GENERATION CONVENTIONAL (HYDRO- COAL, OIL, AND GAS)				
TURBINES	HIGH TEMP. ALLOYS, RESIST. CORR., EROSION AND WEAR	ADV. CERAMIC TURBINE BLADES	MICROPROC. CONTROL	
GENERATORS & MOTORS	SUPERCOND. NbTi	ADV. CERAMIC INSULATORS	MICROPROC. CONTROL	POLYMER-CERAMIC INSULATORS
STORAGE & AUX.	HIGH TEMP. BATT., CATALYSTS FOR FUEL CELLS	ADV. CERAMIC FOR BATT. & FUEL CELLS		
WASTE MANAGEMENT & EMISSIONS CONTROL	CATALYSTS	POROUS SUB- STRATES, FILTER MATERIALS, SYNTHETIC MINERALS		

FIGURE 1.

IMPACT OF SPACE SCIENCE AND TECHNOLOGY	
BENEFITS	
— ECONOMIC:	DIRECT-----SALES, CONTRACTS AND JOBS. INDIRECT-----TECHNOLOGY SPIN-OFFS. WEATHER PREDICTION. SATELLITE SURVEYS.
— SCIENTIFIC:	GAINS IN KNOWLEDGE. TECHNOLOGY, EXPERIENCE, TRAINED SCIENTISTS, ENGINEERS AND TECHNICIANS.
— TECHNOLOGICAL:	SPIN-OFFS IN HARDWARE, SENSORS, ELECTRONICS, ACTIVE DEVICES. IMPROVED MATERIALS & PROCESSES.
— SOCIOLOGICAL:	GLOBAL COMMUNICATIONS, SHARED SCIENCE AND TECHNOLOGY, TREND TOWARD A GLOBAL COMMUNITY.
— POLITICAL:	PEACEFUL USES OF SPACE, SHARED EARTH, ATMOSPHERE AND OCEANS.

Fig. 3.

## FUTURE: MATERIALS AND TECHNOLOGICAL NEEDS

	METALS	CERAMICS	SEMICONDUCTORS	COMPOSITES
<b>POWER DISTRIBUTION</b> (EHV AND UHV)				
CONDUCTORS	COMBINED WITH— (CU, AL, ALLOY)	CERAMIC SUPER- CONDUCTORS		METAL + SUPER- CONDUCTOR
INSULATORS		ADV. CERAMICS		POLYMER-MATRIX AND CERAMIC- MATRIX
TRANSFORMERS	COMBINED WITH— (CU, AL, ALLOY)	CERAMIC SUPER- CONDUCTORS		AMORPHOUS METAL COATINGS
CIRCUIT PROTECTION	* * * *	* * * *	DOPED III-V OR II-VI . CRYSTALS	METAL FOAM AND METAL-MATRIX
FAULT DETECTION & TRANSIENT MEASUREMENT		SUPER-COND. SENSORS, FIBER OPTIC & PHOTONIC DEVICES	SUPERCOND. JUNCTIONS. MICROPROC.	
<b>POWER GENERATION</b> CONVENTIONAL				
TURBINES	HIGH TEMP. ALLOYS	ADV. CERAMIC TURBINE BLADES	IMPROVED MICROPROC. CONTROL	
GENERATORS & MOTORS	COMBINED WITH— (CU, AL, ALLOY)	CERAMIC SUPER- CONDUCTORS		
STORAGE & AUX.	* * * *	* * * *	* * * *	
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## CYTEMP SPECIALTY STEEL DIVISION

BRIDGEVILLE, PENNSYLVANIA 15017 | (412) 221-8000

November 19, 1987

Mr. Craig Voorhees  
National Account Manager  
Boeing Aerospace Operations  
600 Maryland Avenue, SW  
Suite 455  
Washington, D.C. 20024

Dear Craig:

Please accept my apology for missing the Space Station Workshop in Nashville on November 3-5, 1987. As a member of the Industry Working Group and Fabrication Panel, I was certainly interested in a review of the Space Discipline Panels, current efforts and future plans. Of particular interest was the Material Processing in Space sub-panels on Metals and Alloys and Glasses and Ceramics.

As a member of the iron and steel industry, which is massive both in terms of equipment and product, it is not readily apparent what the potential of space technology and the characteristics of the space environment would be for the development of new products and processes. However, the decline of the iron and steel industry due to many factors, not the least of which are competitive materials, makes it imperative that we broaden our horizons if this industry is to remain a competitive force in the world economy. Consequently, I would like to list several brief comments on technology needs and problems facing this industry today.

- (1) **Thin Strip Casting** - The company or country that achieves the technology capability of casting molten metal directly to a thin strip product with uniform dimensions and quality will become the world leader in the manufacture of flat product, the major product form in this industry.
- (2) **Ladle Metallurgy** - The treatment of molten metal prior to casting has assumed major importance because of the need to control cleanliness and second phase particles that affect to a great extent the quality of the final product.
- (3) **Solidification** - The freezing of molten metal, simple or complex alloys, continuous cast or ingot product, can result in segregation or second phase distribution that seriously impairs the quality of final product. This concern has, and continues to be, a major industry problem.
- (4) **Process Parameters** - The entire industry needs faster and more advanced techniques for the measurement of critical process parameters during manufacturing. Process control requirements could be met more easily with precise temperature measurements of molten metal and hot steel, direct in line laser measurement of molten metal chemistry as well as surface defects and size, ultrasound measurement of internal quality, etc.

- (5) **Powder Metallurgy** - The manufacture of near net shapes with associated advantages, as well as the development of complex materials, is afforded by powder metallurgy technology. However, new technological problems in both the manufacture and evaluation of this product has delayed commercial implementation.

What interaction a space environment of micro-gravity or vacuum would have with some of the industry's aforementioned areas of interest is not clearly delineated but could result in designed experiments that may prove beneficial. While the production of iron and steel products in space is not very likely, the establishment of a fundamental understanding in certain areas could materially aid current manufacturing operations.

The current Materials Processing Panel is already addressing some specific areas of interest to the iron and steel industry. These include such programs as directional solidification, metal matrix composites, superalloys, immiscible alloys and containerless processes. It must be remembered that while the bulk of the iron and steel industry involves carbon steels, a smaller but highly critical segment involves specialty steels and complex non-ferrous materials.

As we discussed on the telephone, I would be happy to discuss these areas in more detail if some of our space experts feel there is some synergism in our needs. It would indeed be foolish to let a foreign nation exploit this national resource instead of our own industries.

Sincerely,

L. W. Lherbier  
Vice President - General Manager  
Technology

LWL/dma



Space Station

Commercial Users Workshop

## INDUSTRIAL SERVICES INDUSTRY WORKING GROUP PRESENTATIONS

- Waste Management  
Dr. Peter Vardy, Waste Management, Inc.
- Communications and Information Processing  
Dr. Lou Lanzerotti, AT&T Bell Laboratories
- Health Care Industry  
Dr. Ronald Weinstein, Corabi International Telemetrics
- Delivery Service Industry  
Mr. Jason Wellikoff, Federal Express Corp.
- Electrical Power Delivery  
Mr. Dave Christensen, Pacific Gas & Electric

## WASTE MANAGEMENT INDUSTRY

Dr. Peter Vardy, Vice President, Environmental Management for Waste Management, Inc., spoke on topics in the solid waste, chemical, toxic, and hazardous waste business. He discussed problems in the areas of waste site characterization and site monitoring, and addressed possible space applications for remote water monitoring and incinerator ship monitoring. Other key points and topics were:

- Concern of allaying public fears in the areas of incineration and disposal of toxic and hazardous waste.
- Site characterization for finding an environment that is naturally protective is being inhibited by the "NIMBY," or "Not In My Backyard" syndrome.
- Monitoring regulations and corrective action provisions escalate costs of site monitoring.
- Potential use of fiber optics to monitor without the actual removal of water from the ground could lower the cost of current chemical analysis of extracted water samples.
- Remote sensing applications could be used to monitor the performance, such as stack emission and water impact, of incinerator ships in the North Sea.

## COMMUNICATIONS/INFORMATION PROCESSING

Dr. Louis J. Lanzerotti, AT&T Bell Laboratories, discussed the technology needs for the communications/information processing industry. Dr. Lanzerotti spoke of the scientists as the drivers of new technology and science, and that the risky environment of space would specifically affect the way these stellar scientists would do research. He discussed progress in the areas of transmission, switching and in new devices. Other key points and topics were:

- A different type of research is required (rapid feedback, less risky, etc.) for the space environment and that scientists, not management, will decree the use of space.
- Tight integration of ground and satellite space systems exists in the area of transmission and switching. Land and ocean systems are large and growing and are repairable with no delay. Knowing this, it is unclear at this time the size of a market for cellular access to remote areas using spacecraft.
- The space environment offers certain opportunities for pure materials in the area of new devices. However, defect free silicon and gallium arsenide (GaAs) can be made on earth.
- NASA needs to be aware of how scientists will view the new possibilities of space and needs to reduce the hassles involved in the use of space.

# Telepathology and the Networking of Pathology Diagnostic Services

Ronald S. Weinstein, MD; Kenneth J. Bloom, MD; L. Susan Rozek, RN

• Telepathology is the practice of pathology over a long distance. Components of a telepathology system include the following: (1) a remote-controlled light microscope attached to a high-resolution video camera; (2) a pathologist workstation incorporating controls for manipulating the microscope and a high-resolution video monitor; and (3) a telecommunications linkage. An immediate challenge is to establish the specifications for a telepathology system. Breast tissue has served as a model. Receiver operator characteristic curve studies show that the pathologist's ability to discriminate benign from malignant breast tumors is similar using either a conventional light microscope or a video monitor with approximately 1000 lines of resolution. The percentage of cases for which pathologists render an "equivocal" diagnosis is the same for the two modalities. Telepathology may be an effective way to provide on-line consultations in difficult cases and to provide hospitals in remote areas with immediate access to anatomic pathology services.

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Telepathology is defined as the practice of pathology at a distance by visualizing an image on a video monitor rather than viewing a specimen directly through a microscope.<sup>1</sup> Although in its infancy, several trends in laboratory medicine seem to favor the development of telepathology. These include the emergence of centralized reference laboratories,<sup>2</sup> the creation of financial incentives to spin-off certain in-house hospital operations including some laboratory services,<sup>3,4</sup> the growth of subspecialization within the field of pathology, and an increasing emphasis on quality control and quality assurance.<sup>5,7</sup> In the future, as in the past, technology innovation will play a significant role in defining the job descriptions of health care professionals, including pathologists.<sup>8</sup> Advances in computer science, telecommunications, and engineering will hasten laboratory centralization while simultaneously increasing the availability of subspecialty pathology services throughout the health care system. Such trends would have an impact on both how and where pathologists practice medicine in the future.<sup>4,8</sup>

Some insights into the pathology practice of the future may be deduced from radiologists. Although pathologists may view the practice of radiology as being very different from the practice of pathology with obvious justification, there are similarities as well. Recent technological advance-

ments in radiology are applicable to pathology, although the transfer of the technology from one specialty to the other is just beginning to take place. For example, advances in the development of the digitalized radiology department<sup>9,10</sup> and the introduction of teleradiology as an approach to delivering radiology diagnostic services off-site<sup>11,12</sup> may foretell what could happen to the practice of anatomic pathology in the future. Dramatic improvements in the technology for capturing and storing digitized images<sup>13</sup> and the introduction of high-definition television could have important implications for both radiology and pathology. Also, telemedicine networks are being created and used by radiologists at national institutions. A dedicated broadband satellite telecommunication network was placed in operation by the Mayo Clinic, Rochester, Minn, in 1986 to provide telemedicine services between the Rochester clinic and the new clinic in Jacksonville, Fla. Another clinic in Scottsdale, Ariz, will join the network later. Specialty radiologists in Rochester are currently using the system to evaluate patients in Jacksonville, and the Mayo Clinic's Department of Pathology has plans to bring telepathology services on-line in 1987 (George M. Farrow, MD, unpublished observation, 1986). The Mayo Clinic experience will be followed with interest by health care planners as a model for the delivery of high-quality medi-



cal services to distant sites using modern telecommunication technology. The potential use of telemedicine by the Mayo Clinic as a marketing strategy has been noted by its competitors.<sup>14</sup>

This article provides a summary of the development in the field of telepathology. A brief historical overview of telemedicine is followed by a consideration of several topics, including telepathology system design, technical aspects, and medical technology assessment. A meaningful discussion of the economics of telepathology is beyond the scope of this article, although it should be noted that the costs of the hardware and software components of a telepathology system are rapidly declining. Furthermore, other factors, such as business strategies of multiunit hospital chains and corporate medicine,<sup>14,15</sup> liability issues<sup>16</sup> (*American Medical News*, June 14, 1985, pp 3,9), telecommunications policy,<sup>17,18</sup> and attitudes of health care professionals and the public, may play a greater role in determining the success or failure of telemedicine in general, and telepathology in particular, than the costs of telepathology systems.

## HISTORICAL OVERVIEW

Telecommunication systems have been employed sporadically to deliver health care services since 1959, when Albert Jutra, MD, pioneered telerradiology by interlinking two hospitals in Montreal, five miles apart, with coaxial cable to transmit videotaped telefluoroscopy examinations. He proposed that a special telecommunications network be established interconnecting hospitals and physicians' offices to speed up the exchange of roentgenologic information.<sup>19</sup> Also in 1959, Cecil Wittson, MD, director of the Nebraska Psychiatric Institute, Omaha, linked the Institute with the University of Nebraska College of Medicine located across the street, to "promote discourse between psychiatry and the other medical disciplines." Subsequently, a microwave link was established between the Nebraska Psychiatric Institute and the State Mental Hospital in Norfolk, 112 miles away, resulting in improved medical

services, education, and patient transfer. As recounted by Carey,<sup>11</sup> the essential change that occurred was in attitude. Telemedicine noticeably elevated the self-esteem of the staff at the Norfolk facility.

In the 1970s, a wide assortment of telehealth projects explored many potential applications including direct patient care, clinical consultation, training, education, and management. The US government played the major role in promoting and funding the projects, based on the belief that interactive telecommunication provides a way to improve access to medical services and to overcome the restraints of time, distance, and the maldistribution of medical resources. Although some of the projects were successful in demonstrating the usefulness of the technology, they usually folded when funding ran out because they could not be self-sustained.<sup>11</sup> However, accelerated interest in the potential of telemedicine accompanied spectacular advances in computer technology in the late 1970s.

Telepathology, per se, has received relatively little attention compared with telerradiology, due to several limiting assumptions: (1) that monitor resolution beyond the capability that currently exists would be required for telepathology; (2) that bidirectional communication would be required for the manipulation of an off-site robotic microscope, since the responsible pathologist at a diagnostic workstation or hub would need to control the microscope and stage movements by remote control; and (3) that image digitization would require vast amounts of storage capacity and very broad bands for transmission of full-color images at high resolution. All of these assumptions have merit, although new technologies may help minimize some of these issues.

Despite these concerns, there have been efforts to experiment with telepathology. A demonstration of the potential usefulness of telepathology occurred in 1973. Static black-and-white images of peripheral blood and bone marrow smears from a 17-year-old boy in respiratory distress were transmitted from the ship SS Hope, docked in Brazil, via satellite (INTEL-

SAT, International Telecommunications Satellite Organization, Washington, DC) to the Project Hope office in Washington, DC. Physicians aboard the ship summarized the patient's history and physical findings while consultants in Washington viewed the pathology specimens, roentgenograms, and other visual materials on video monitors. A diagnosis of mediastinal lymphosarcoma with leukemic transformation was rendered and treatment was instituted.<sup>20</sup> The telepathology segment of the demonstration did not involve the use of a high-resolution color camera/monitor system or a remote-controlled microscope. However, it did demonstrate the potential usefulness of telecommunications for the long-range delivery of pathology services.

A local telepathology network was installed in 1983 at Rush-Presbyterian-St Luke's Medical Center, a large 1000-bed university hospital complex in Chicago. The network enables transmission to full-color frozen section images from the Department of Pathology in the laboratory building to ten operating rooms in another building for purposes of report generation, immediate consultation, and education. The telepathology network has been in daily use since it became operational, and has become an integral part of the service and training programs at Rush-Presbyterian-St Luke's Medical Center.

On Aug 20, 1986, in a demonstration organized in part by the authors of this article, telepathology was used by a faculty member from Rush Medical College, Chicago, to render a diagnosis on a breast tissue frozen section prepared at Fort William Beaumont Army Medical Center, El Paso, Tex, at a public display of the technology (*Washington Post*, "Health" section, Aug 27, 1986, p 7). Staff members from the Armed Forces Institute of Pathology, Washington, DC, and the US Surgeon General's office, members of the academic community, and representatives of the media were present. In Texas, the frozen section slide was placed on the stage of a custom-designed, fully motorized light microscope (Olympus Vanox, Olympus Corp, Lake Success, NY)

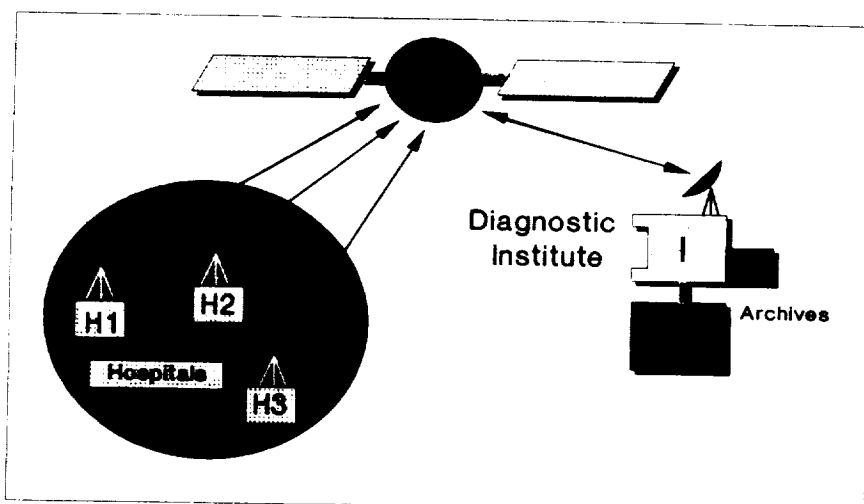


Fig 1.—Telepathology system includes referral hospitals (H1, H2, and H3), telecommunications linkage, and diagnostic institute (I) or hub. Reports may be archived at hub (A1) or at regional archive (A2). Communications within system are bidirectional.

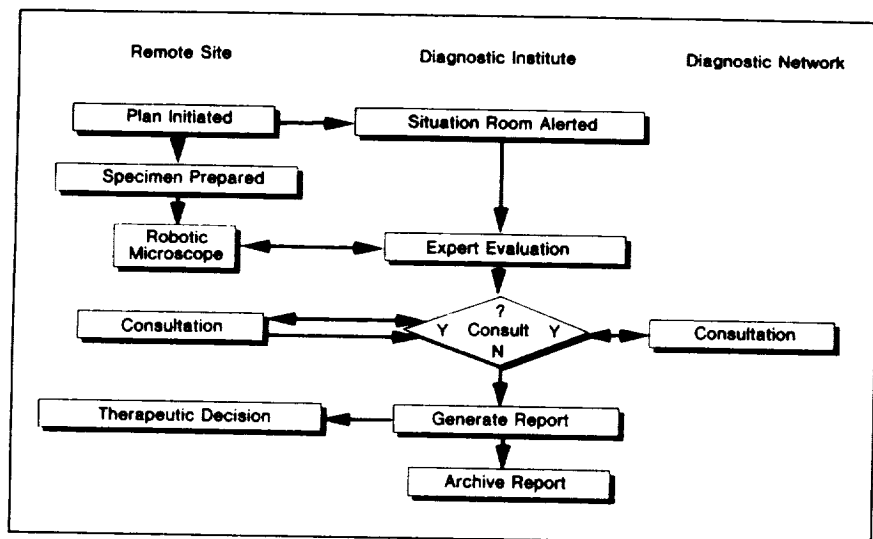


Fig 2.—Flow diagram of procedure for rendering frozen section diagnoses using telepathology. See text for details.

equipped with a video camera (Ikegami Electronics [USA] Inc, Maywood, NJ). An image of the moving specimen was transmitted in full color to the COMSAT (Communications Satellite Corp, Washington, DC) building in downtown Washington, DC, via the SBS-3 COMSAT satellite. In Washington, while seated at a prototype of the Corabi DX-1000 workstation (Corabi International Telemetry, Rockville, Md), the pathologist had complete control of the microscope's stage movements, magnification, focus, and illumination,

using software developed by Corabi. The moving image was viewed in real time at various magnifications on a video monitor with 525 lines of resolution. A second monitor displayed the following information: (1) a graphic representation of the slide indicating the location of the image being transmitted, in one window; (2) stage  $x$  and  $y$  coordinates, stage speed, microscope illumination intensity settings, and other microscope control parameters, in a second window; and (3) patient demographic information, in a third window. Two-way audio communica-

tion was maintained throughout the procedure between the physicians in Texas and the pathologist in Washington. Pathologists present at the demonstration were reported to be impressed by the quality of the image and by the ease with which the pathologist in Washington could control microscope stage movements in Texas (*Washington Post*, "Health" section, Aug 27, 1986, p 7).

#### TELEPATHOLOGY SYSTEM DESIGN

The essential components of a telepathology system are the following: (1) a motorized light microscope equipped with a high-resolution camera (located at a remote site where surgery or a fine-needle biopsy is performed); (2) a pathologist's workstation with controls for the motorized microscope and two monitors, including a system control monitor and a high-resolution video monitor for viewing the specimen (located at a diagnostic institute or hub), and (3) a communications linkage between the remote site and the diagnostic hub (Fig 1). Other potentially useful components include a macroscopic television camera with a remote-controlled zoom lens for examination of the gross specimen, a robotic laser pointer to allow the pathologist at the diagnostic hub to point to the areas of interest in the gross specimen, and possibly a small-parts ultrasound system (eg, a tactile emulator) to enable the pathologist at the diagnostic hub to map the specimen for areas of firmness or calcification.

The design of the telepathology system can best be explained by considering how the system would be used to perform a diagnosis on an actual specimen, such as a piece of tissue removed for frozen section diagnosis. It should be stated that frozen section diagnoses are not regarded as the major potential application of the technology. Expert on-line consultation in difficult cases may be a more important application. Figure 2 is a flow diagram showing the steps involved in rendering a frozen section diagnosis using telepathology. At the beginning of the surgical procedure, personnel at the site of the surgery (called the "remote site") electronically notify the "situation room" at the

central diagnostic institute. Pathologists at the hub are placed on alert. After the specimen is obtained and the frozen section tissue is processed, the slide is placed on the stage of the robotic microscope. Control of the microscope reverts to the pathologist at the diagnostic institute (eg, the hub). The patient's history is transmitted to the diagnostic hub over an audio channel. The expert pathologist at the diagnostic hub may render a diagnosis, ask for additional information, or show the slide to another expert, either on site at the hub or at an affiliated hub within the diagnostic network. After the diagnosis is rendered, a report is generated and immediately transmitted to the remote site by electronic mail. It is simultaneously archived along with a recording of the video broadcast. The surgeon, in consultation with a participating pathologist at the remote site, proceeds to make a therapeutic decision.<sup>1</sup>

#### TECHNICAL ASPECTS

For many teleradiology applications, such as computed tomographic scan studies, static monochrome images are transmitted in a batch mode. Telepathology is more demanding on communications systems since moving images in full color are transmitted in real time. Another major difference is that many radiology imaging techniques now routinely generate data in a digitized format in black and white. There is vastly more information in a single light microscopic field of a tissue section than in a computed tomographic scan image. Although the technology to digitize light microscopic images has existed for many years,<sup>13,21</sup> the amount of information thus captured cannot be stored and transmitted in real time using commercially available satellites. This capacity is likely to be available in the future.

The specifications and current availability of the essential components of a telepathology system, namely, a motorized light microscope, a super high-resolution camera and monitor, and a broadband telecommunications system, will be considered individually.

#### Robotic Light Microscopy

Motorized, computer-controllable light microscopes that fulfill the requirements for telepathology have been assembled from off-the-shelf components. Software is being developed by Corabi International Telemetrics to further facilitate the mapping of the tissue sections on glass slides and the tracking of the pathologist's fields of observation to ensure that sections on a slide are examined in their entirety. This is critical, since the pathologist at the diagnostic hub will not have the slides "in hand." All of the controls for the motorized light microscopes, including magnification, stage movement, focus, and intensity controls, can be transmitted over conventional telephone lines or by satellite.

#### Camera/Monitor Systems

Specifications for a telepathology system are determined, in part, by the requirement of the production of an image by a camera/monitor system of adequate quality to permit a pathologist to render a diagnosis with the same accuracy achievable using a conventional microscope. Camera/monitor resolution and microscope resolution need not be identical, since it is possible that the quality of the image in a light microscope may actually exceed that required for pathologists to render accurate diagnoses in some settings. Preliminary evaluations of several different systems, utilizing tissue sections and resolution test slides, indicate that standard television resolution, 525 lines, is inadequate for some pathology diagnostic applications (R.S.W., K.J.B., L.S.R., unpublished observation, 1986), but that high-definition television may be adequate for the analysis of many specimens (Fig 3).

Formal evaluation of a 1000-line resolution telepathology system has been conducted at Rush-Presbyterian-St Luke's Medical Center using established technology assessment methodology.<sup>22-26</sup> Diagnostic accuracy can be measured in a variety of ways. One approach is to measure sensitivity, specificity, and the proportion of true-positive responses. A limitation is that these parameters do not assess

the pathologist's "confidence" or decision threshold. Simply stated, they do not address the *tendency* of individual diagnosticians to overcall or undercall disease.

In 1979, Swets et al<sup>23</sup> described a protocol that serves as an excellent guideline for the evaluation of diagnostic devices.<sup>23,27-29</sup> The protocol involved the assessment of actual cases in order to determine the modalities' discriminative abilities as judged by independent, external evidence. Performance data were then generated in terms of a receiver operator characteristic (ROC) curve. The ROC curve is a measure of the discriminative power of a diagnostic modality and is independent of "extra-image" information such as patient age.

Receiver operator characteristic curve analyses address some problems that are inherent in laboratory testing. Unless a diagnostic test has 100% sensitivity and specificity, there will be some overlap between test results for diseased and nondiseased patient populations, or, in patients with tumors, for patients with benign and malignant lesions. For example, the ability to distinguish benign from malignant lesions measuring a single quantitative feature, such as the mitotic rate, can result in a considerable region of uncertainty. The decision threshold as to the number of mitoses that must be present to constitute malignancy can vary from a very low rate at one extreme to a very high rate at the other extreme. Each decision threshold will result in a unique sensitivity and specificity for mitotic rate as a discriminator of malignancy. The ROC curve is created by plotting the true-positive ratio (sensitivity) vs the false-positive ratio (1-specificity), as the decision threshold is varied from one extreme to the other. In the context of pathology, an ROC curve is a measure of the number of true-positive decisions vs the number of false-positive decisions the pathologist will make. The area under an ROC curve is representative of the discriminative ability of a specific feature (eg, numbers of mitotic figures) using a specific diagnostic modality.<sup>28</sup>

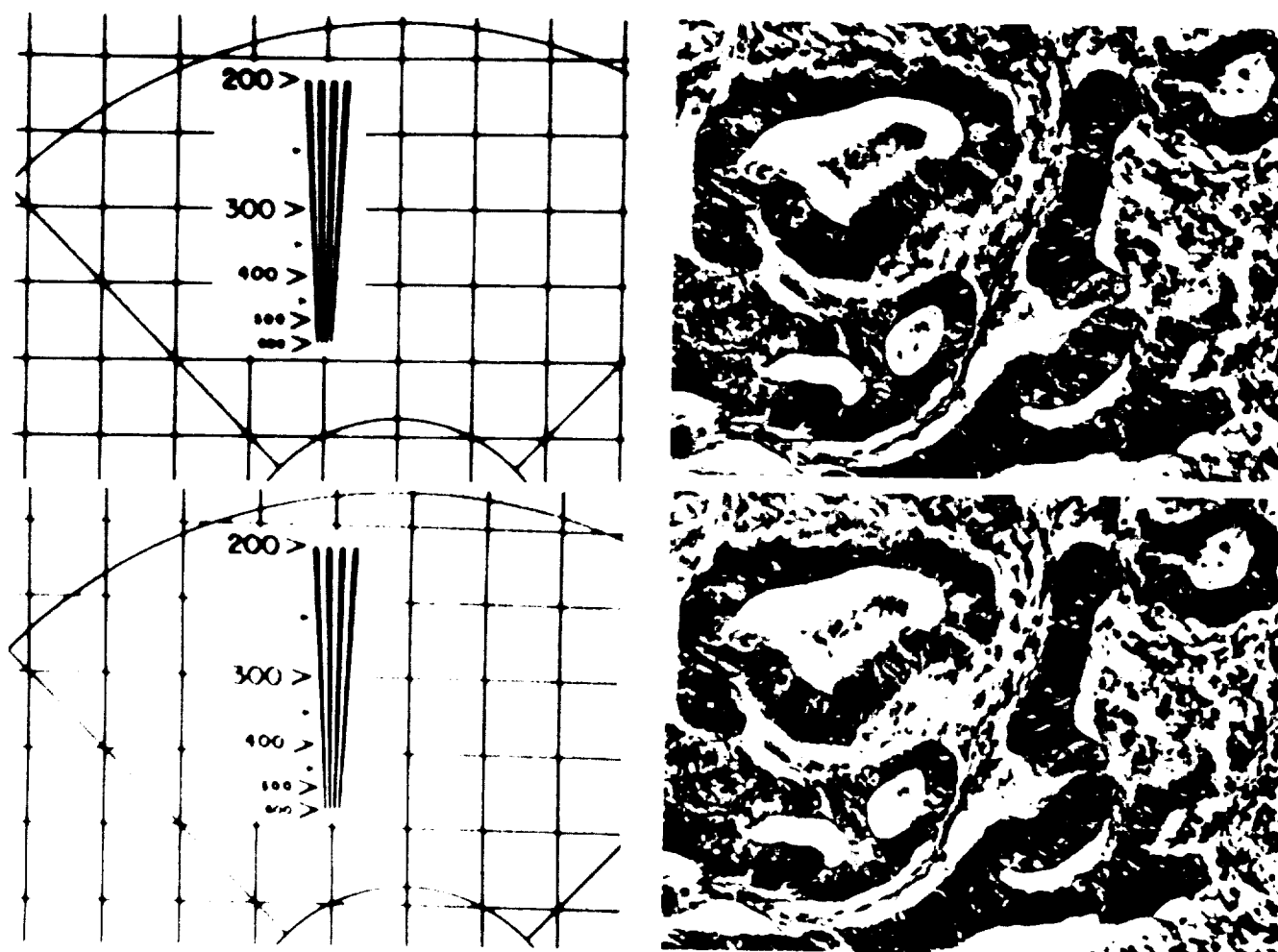


Fig 3.—Comparison of images obtained by conventional photomicroscopy (top) and video microscopy (bottom). Video camera (Sony model SHR-10) with 1050 lines of resolution was used for video microscopy. Photographs on bottom are of screen of 950-line video monitor (Sony Trinitron) and were taken with 35-mm camera. Top left, Photomicrograph of test grid etched on surface of glass microscope slide (magnification,  $\times 100$ ); bottom left, Test grid image on video monitor screen (magnification,  $\times 100$ ); top right, Photomicrograph of paraffin section of colon cancer (hematoxylin-eosin,  $\times 250$ ); bottom right, Identical field of same section of colon cancer viewed on video monitor screen.

Applying ROC curve analysis to histopathologic decision-making necessitates finding independent evidence to assess the validity of the diagnosis. Long-term follow-up of untreated persons would best fulfill this criterion. It is impractical, if not impossible, to assemble such a study set with a sufficient number of patients. As a compromise, "truth" can be assigned on the basis of rereview of cases with additional, albeit incomplete, follow-up data before the cases are included in the study.

We have performed ROC curve analyses of pathologist performance diagnosing frozen sections on a video monitor, an essential component of a

telepathology system. The test material was breast tissue from 115 consecutive frozen section cases at Rush-Presbyterian-St Luke's Medical Center. The study was performed retrospectively on the frozen section slides prepared at the time of the original frozen section diagnosis. The discriminative abilities of six staff pathologists in differentiating normal breast and benign breast lesions from malignant breast tumors was assessed. Each pathologist reviewed all 115 cases twice, once by light microscopy and once by video microscopy. Individual cases were reviewed at least one month apart. Performance was judged on the basis of the original

frozen section diagnosis, with the stipulation that rereview of the original frozen section(s) after the entire case was analyzed did not alter the original frozen section diagnosis. If the original diagnosis was found to be incorrect or incomplete, the reinterpreted frozen section diagnosis was used. The test set of 115 cases consisted of 68 malignant specimens and 47 benign specimens.

The six pathologists completed a standard institutional frozen section report form for each case. They then assessed the case on a scale of 1 to 5, where category 1 represented an absolutely benign lesion, 2 represented a lesion that was probably benign, 3

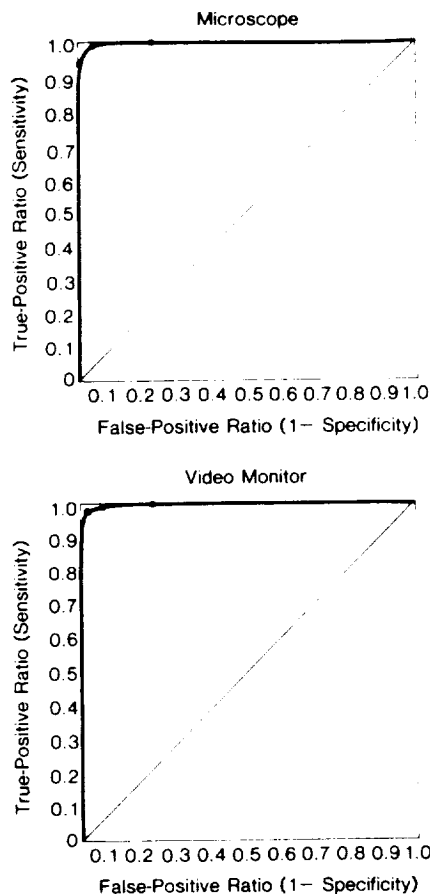


Fig 4.—Receiver operator characteristic curve analyses comparing diagnostic performance of pathologist examining study set consisting of 115 frozen section breast biopsy cases by conventional light microscopy (top) and video microscopy (bottom). Curves demonstrate identical discriminative ability.

represented an equivocal lesion, 4 represented a lesion that was probably malignant, and 5 represented an absolutely malignant lesion. Categories 2, 3, and 4 comprise the "equivocal zone" within the diagnostic spectrum.

The ROC curve analysis was performed according to the rank method.<sup>28</sup> Figure 4 shows the ROC curves for one of six pathologists who viewed the test set of the 115 cases using both the light microscope and video monitor. The ROC curves for this pathologist were virtually identical, showing that a pathologist can distinguish benign from malignant breast lesions with equal ability using either system. Of the other five pathologists, three had marginally better performance with the light microscope, whereas two had marginally better perfor-

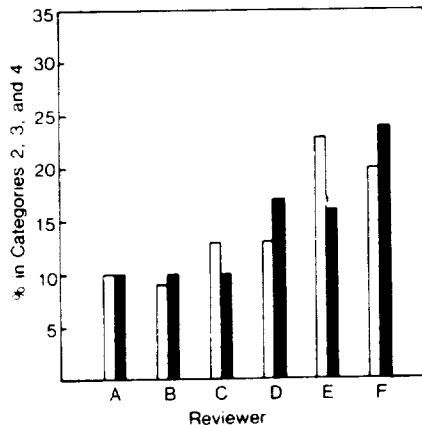


Fig 5.—Equivocal zone analyses of diagnoses on breast frozen sections by six pathologists (A through F). For each pathologist, percentage of cases for which diagnosis of benign or malignant was made with less than 100% certainty (categories 2, 3, and 4) are shown for each of two modalities, light microscopy and video microscopy. Open bars indicate light microscopy; solid bars, video microscopy.

mance with the monitor. Degrees of diagnostic equivocation are shown in Fig 5. There is a correlation between equivocal zone percentages for individual pathologists using the two modalities (correlation coefficient, .713). Pathologists with a greater tendency to place cases in the "equivocal" category did so with both modalities. Caution must be exercised in extrapolating these results to other tissues, to other diagnostic problems, or to other camera/monitor systems. Many additional studies must be done to determine the range of applications for the technology.

#### Telecommunications System

Transmission via satellite of the noncompressed video signal from the 1000-line super high-resolution video camera used in our ROC curve studies would require a bandwidth of 30 MHz, which is far broader than the bandwidth of the National Television System Committee standard (4.2 MHz) used in the United States and Japan for commercial broadcasting. Although transponders on satellites can accommodate bandwidths of 36 MHz or more, the interfaces that would be required to handle the 30-MHz signal from a super high-resolution camera do not exist. Furthermore, transmis-

sion at this bandwidth would be very expensive, even in the face of the current glut of satellite transponder time. Generally, bandwidth requirements are directly related to transmission costs.

There are several strategies that may significantly decrease the bandwidth requirements for telepathology in the future. One will be to use high-definition television in combination with signal compression, technologies that are tentatively scheduled for widespread implementation in the 1990s<sup>10,31</sup> and hold considerable promise for telepathology. The most highly developed system introduced to date offers a resolution of 1125 lines, and is claimed to produce pictures approaching the quality obtainable by photomicroscopy with 35-mm film.<sup>32</sup> The video signal from a high-definition television camera has a bandwidth of approximately 30 MHz, but this can be markedly reduced using a data compression system. The first such system demonstrated over an experimental public broadcasting system in the United States is MUSE (multiple sub-Nyquist sampling encoding), developed by NHK, Japan's broadcasting network. The MUSE compression system reduces the 30-MHz bandwidth video signal to 8.1 MHz. Up to four data and/or audio channels can be digitally encoded and transmitted with a video signal in a 10-MHz bandwidth.<sup>32</sup>

A second strategy to reduce bandwidth requirements for telepathology involves the development of scene segmentation algorithms. Pathologists use panoramic scanning to examine slides. As the specimen stage moves the slide, additional data are added to one quadrant of the visual field as previously examined data are deleted from the opposite quadrant. Since a relatively small amount of data are added and deleted within the time frame of one thirtieth of a second, the vertical sweep rate for conventional television, it is theoretically possible to transmit the incremental data at a small fraction of the rate required to transmit all of the data in a given field. Once the data required to fill out the initial microscopic field are displayed, additional data would be

added incrementally at the downstream edge of the microscopic field.

## IMPLEMENTATION

Interest in telepathology is increasing for a number of unrelated reasons. The proliferation of multiunit hospital chains and vertical integration in health care systems are factors. The need to deliver quality health care conveniently to rural or remote areas is another (*American Medical News*, Oct 24/31, 1986, pp 11-12). The availability of much of the required technology and equipment in the form of off-the-shelf products is encouraging systems integrators to explore the commercial market for telepathology systems. Intense interest on the part of radiologists in extending their practice base using teleradiology has already created a market for teleradiology equipment. This is being promoted by major players in the medical equipment field. It seems inevitable

that this, in addition to the proliferation of free-standing imaging centers in the United States, will stimulate interest among pathologists who wish to promote comparable developments in their own field.

The time frame in which telepathology will become a reality as a means of providing diagnostic services on a significant scale is more difficult to predict. In settings where neighboring facilities can be linked by coaxial cable, telepathology systems could be installed within a brief time frame, since appropriate video equipment has been identified and is being marketed, and prototype telepathology workstations have already been constructed and tested. Plans for commercial models are well beyond the drawing board stage of development. For applications requiring greater transmission distances, some significant technological hurdles remain. The largest obstacle is in developing

the interfaces between super high-resolution video cameras, high-resolution video monitors, and telecommunication systems. Although the technology to do this is close at hand, the schedule for implementation remains an unresolved question. Success in using telemedicine to facilitate the dissemination of subspecialty expertise within multiunit hospital systems or the creation of broadband health care networks onto which telepathology communications linkages might be piggybacked would accelerate the transfer of telepathology from the laboratory into medical practice.

We gratefully acknowledge the participation of John R. Dainauskas, MD, Beth L. Johnson, MD, Jerome M. Loew, MD, Alexander W. Miller III, MD, Daniel Schwartz, MD, and Alexander C. Templeton, MD, in the receiver operator characteristic curve studies. We thank William B. York, Jr, MD, Paul Kordis, MD, and Ronald W. McLawh, MD, for useful suggestions, Sandra L. Velasco for help in preparing the manuscript, and Lester Wolf, Mary C. Weinstein, and Lisa Yaremko, MD, for technical assistance.

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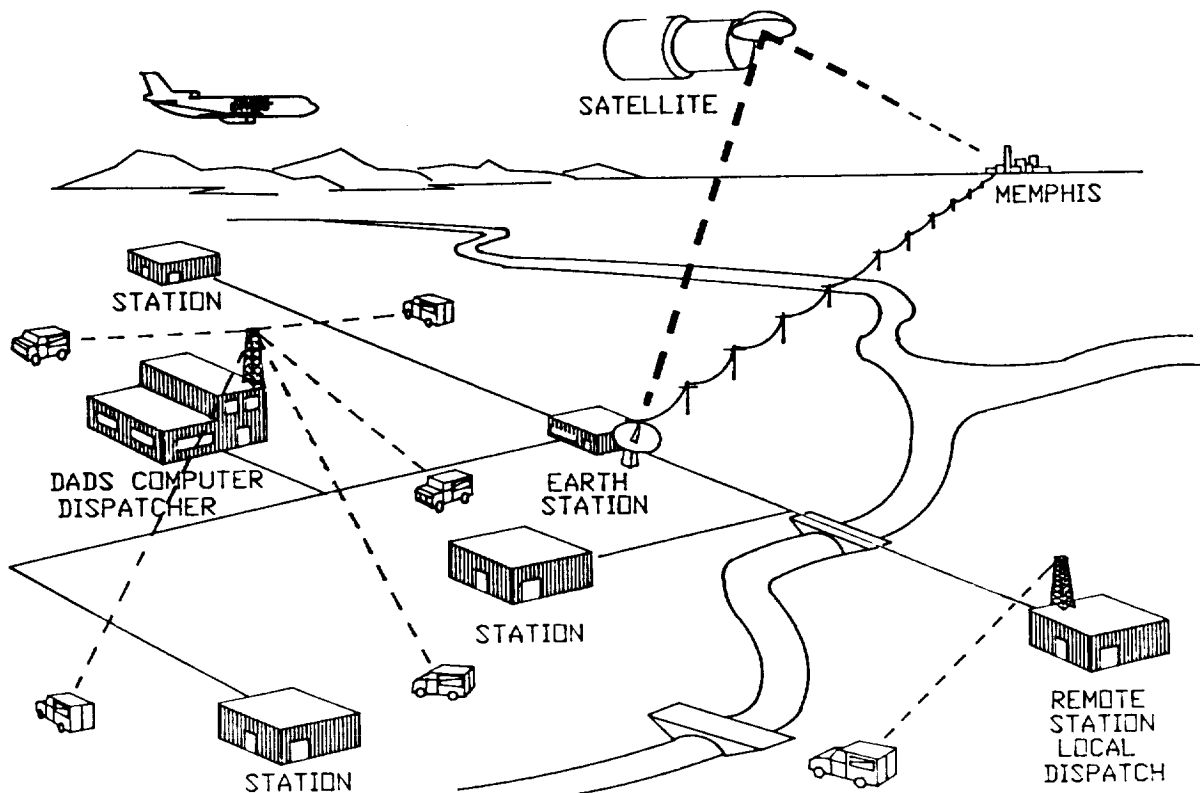
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# FEDERAL EXPRESS CORPORATION

## PROBLEMS OF THE FUTURE

NOVEMBER 3, 1987  
JASON R. WELLIKOFF    RICHARD C. BRALEY

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FEDERAL EXPRESS CORPORATION

# PROBLEMS OF THE FUTURE

## TRANSPORTATION COSTS

- CONTROL THE COST AND TIME REQUIREMENTS OF TRANSPORTATION
- COST AND AVAILABILITY OF FUEL
- EFFICIENCY IN MATCHING LIFT TO LOAD
- FASTER TRANSPORT (AIR AND GROUND) WITH LESS TRANSIT TIME

NOVEMBER 3, 1987

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# PROBLEMS OF THE FUTURE

## TRACKING AND TRACING

- TRACK AND TRACE EVERY RESOURCE AND PRODUCT ON A REAL TIME BASIS
- LOCATION AND IDENTIFICATION
- STATUS REPORTING
- CORRECTIVE ACTION REQUIREMENT

NOVEMBER 3, 1987



## PROBLEMS OF THE FUTURE REAL TIME COMMUNICATIONS

- IMPROVE ABILITY FOR INTERNAL AND EXTERNAL ENTITIES TO ESTABLISH AND MAINTAIN CONTACT FOR TIMELY EXCHANGE OF INFORMATION
  - REQUEST FOR SERVICES
  - STATUS REPORTING
  - BILLING AND ACCOUNTING
  - OPERATIONS CONTROL
- NOVEMBER 3, 1987
- 

## PROBLEMS OF THE FUTURE PACKAGE HANDLING COSTS

- REDUCE RESOURCES REQUIRED TO PICK-UP, UNLOAD, SORT, LOAD AND DELIVER CUSTOMER PRODUCTS AND MESSAGES
- INCREASE PRODUCTIVITY OF RESOURCES
- IMPROVE FORECASTING AND RESOURCE ALLOCATION
- IMPROVE ABILITY TO MATCH RESOURCES TO WORK REQUIREMENTS

NOVEMBER 3, 1987

# PROBLEMS OF THE FUTURE FEDERAL EXPRESS CORPORATION

- TRACKING/TRACING RESOURCES
- TRACKING/TRACING PRODUCTS
- COST OF TRANSPORTATION
- COST OF PRODUCT HANDLING
- NETWORK COMMUNICATIONS
- AIRPORT OPERATION RESTRICTIONS

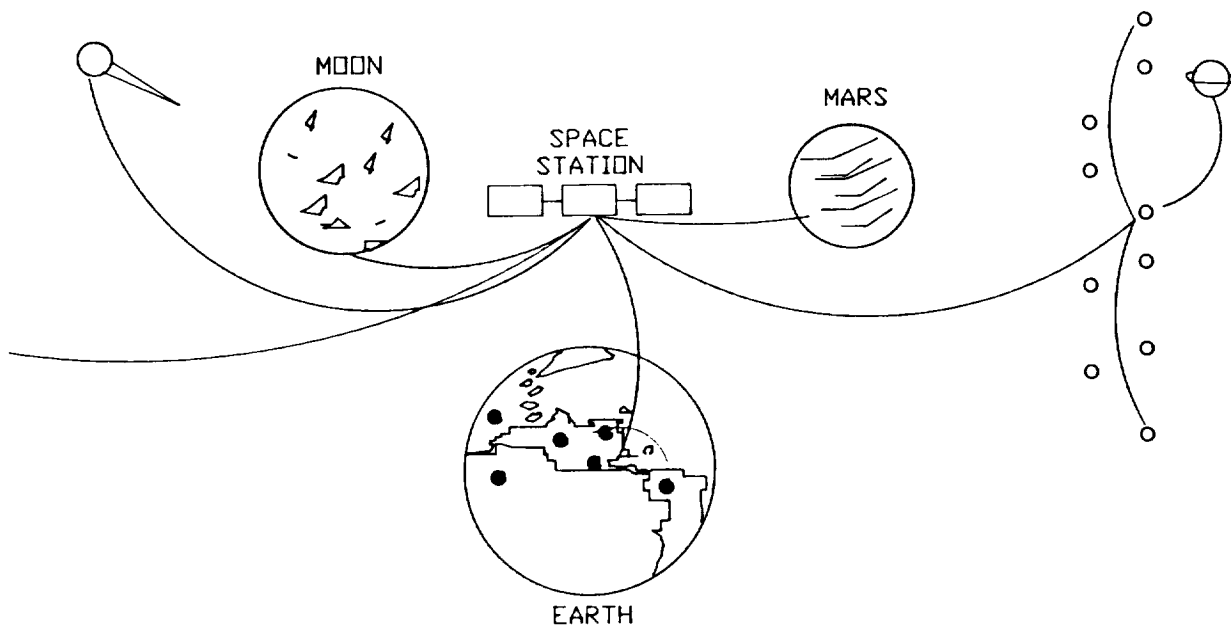
NOVEMBER 3, 1987

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## PROBLEMS OF THE FUTURE AIRPORT RESTRICTIONS

- ELIMINATE RESTRICTIONS ON AIRPORT OPERATIONS TO ALLOW TRANSPORT TO AND FROM CLOSEST POINT TO CUSTOMER
- REDUCE AIR TRAFFIC
- ELIMINATE NOISE RESTRICTIONS/CURFEWS
- INCREASE AVAILABILITY OF AIRPORT RESOURCES
- ELIMINATE WEATHER DELAYS

NOVEMBER 3, 1987



## FEDERAL EXPRESS UNIVERSAL COVERAGE



Space Station  
Commercial Users Workshop

### THE CHANGING UTILITY INDUSTRY

#### 1. Historical Perspective

- natural monopoly
- rapidly growing market
- decreasing costs

#### 2. Future

- more competition
- uncertain loan growth
- increasing sophistication of customer needs

#### Near-Term Needs -- Cut Cost

##### 1. Power Plant Efficiency & Availability

##### 2. Environmental Issues

- acid rain
- hazardous materials
- greenhouse

##### 3. Myriad Operational Improvements

#### Longer-Term -- Flexibility

1. Gas Supply
2. Improved Generation & Conservation





## ASTRONAUT EXPERIENCE

Dr. Jeffrey Hoffman, a mission specialist on Space Shuttle flight 51D, April 1985, gave the Workshop a briefing on his flight experience. Dr. Hoffman showed a film taken during the flight. The flight consisted of launching a Canadian Telesat, launching a Syncom satellite -- which did not operate initially and required unplanned extra vehicular activity, and conducting many experiments and demonstrations of space zero-gravity effects.

Dr. Hoffman discussed the need to get astronaut input into the design of experiments and equipment for the shuttle. Often times the astronauts will see problems with the experiment and have recommended changes, but it is usually too late to change the experiment hardware. Dr. Hoffman announced that the NASA Astronaut Office has formed a Science Support Group to make such hardware expertise available to experiment designers. The Science Support Group can be contacted through the NASA Astronaut Office or through the Boeing/Peat Marwick Commercial Space Group.



## A CONGRESSIONAL PERSPECTIVE

Mr. Dave Clement, Assistant to Congressman Robert Walker (D - Pennsylvania), addressed the Workshop on a congressional perspective of the commercialization of space initiatives and Space Station program. Speaking on behalf of Congressman Walker, Mr. Clement conveyed the Congressman's support of NASA and the commercialization initiatives and he felt confident that NASA was ready to move on following the *Challenger* accident. Mr. Clement commended Mr. Jim Rose on the Office of Commercial Programs and on the new initiatives to facilitate space commercialization. Other key points mentioned by Mr. Clement were:

- Congress has a number of worries about the Space Station. The first is the total cost. The second is the need to balance what is happening on the Space Station program with other NASA initiatives such as returning the Shuttle to flight, redesigning the solid rocket motors, designing and developing an advanced solid rocket motor, and developing the Shuttle cargo component. All of these initiatives will compete for NASA dollars.
- Congress is trying to look at the Space Station from the viewpoint of life cycle cost. Congress will have to fund the program over a 25-30 year life and needs to know, up front, how much it will cost.
- Mr. Clement felt the Workshop was trying to develop an appropriate mission for the Space Station and that the Space Station will be a unique national asset. It will be a national laboratory in space.
- NASA and Congress need strong input from the private sector as to exactly:
  - what commercial missions are viable on-board the Space Station;
  - how to continually evolve and update the requirements and missions of the commercial community on-board the Space Station; and
  - what the private sector needs both in hardware and environment on-board the Space Station, (i.e. what regulations and enhancements the private sector needs).
- Presently, the U.S. spends less than 1% of GNP on space (\$9-10B to NASA). Congressman Walker recommends increasing spending to 2% of GNP by the mid-1990's. The major portion of the new expenditure should come from the private sector. This will be done by greatly expanding commercial opportunities and providing the private sector the opportunity to start building a space infrastructure. Congressman Walker believes that the U.S. needs to see long-term commercial goals in space as is the case in other countries. This Workshop is a major step toward focusing American attention on what our commercial opportunities are on-board the Space Station.



- Congress will try to improve the overall environment for space commercialization by:
  - Holding hearings on establishment of a Department of Space, Science and Technology, that would bring together NASA, the National Science Foundation, and a number of other scientific and technical organizations throughout the government. It would be a central department with cabinet level representation to give a somewhat stronger space and science voice within the administration;
  - Supporting the establishment of a National Space Council under the Vice President and to include the Secretaries of the new Space, Science and Technology Department, Transportation, Commerce, Defense, and State. This council would develop space policy to restore America to the space leadership we once held;
  - Moving space patent legislation in congress. This is to address the fact that current intellectual property and patent laws do not define inventions made in space;
  - Looking at various space tax policies to give the business community a tax break on space investments; and
  - There will probably be a House resolution early in the year that will call on the administration to increase the NASA budget over the next five years by approximately 50%.
- NASA needs to do the following to improve space commercialization opportunities:
  - Provide a positive atmosphere -- one in which commercialization can flourish. The Office of Commercial Programs has taken the first step -- other steps will be required;
  - Take steps to ease the entry of new participants into the space arena;
  - Provide timely flight opportunities and re-flight opportunities;
  - Find ways through NASA and the government to provide for a smooth transition from a basic research program to proven concept and then into the commercial arena.
- Congress (the Sub-Committee on Space Science and Applications) will provide:
  - Continued support for space commercialization;
  - A forum for building public support for commercial activities in space; and
  - A focal point for making new public policy.
- Congress needs outputs from workshops like this to give it a good idea of:
  - Precisely what public policy changes are required;
  - What institutional changes should be encouraged; and
  - A general thrust of what direction the private sector wants to move.





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**SECTION III**

**SPACE DISCIPLINE PANEL**

**SUMMARIES**

**AND RESULTS**





Space Station

Commercial Users Workshop

# **SPACE DISCIPLINE PANELS**

## **OVERVIEWS, DISCUSSIONS, AND SUMMARIES**



## SPACE DISCIPLINE PANELS OVERVIEW

Three Space Discipline panels were established consisting of experts in particular technical areas, NASA, industry, and academic personnel. The panels were to:

- Attempt to match industry requirements identified by the Industry Working Groups with commercial missions currently planned for the Space Station;
- Identify potential new commercial ventures; and
- Identify barriers to commercialization.

Each panel presented an overview to the Workshop plenary, then convened a plenary session for the panel in which overviews specific to that panel were presented. The panels then broke into twelve sub-panels for discussions in the more specific areas.

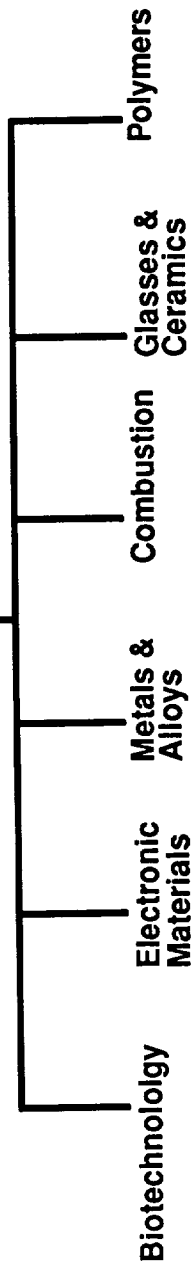
This section contains for each panel:

- Overview material presented to the Workshop plenary session;
- Panel opening plenary summary;
- Sub-panel discussion summaries; and
- Closing plenary summary.

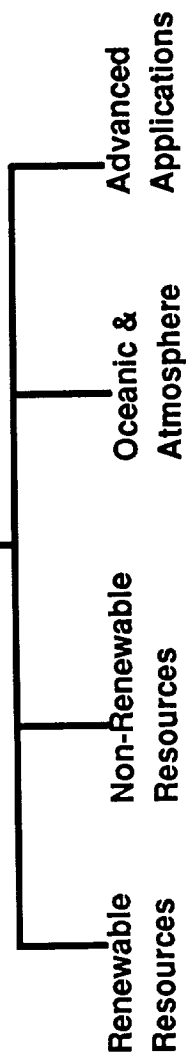


# Space Station Workshop Space Discipline Panels

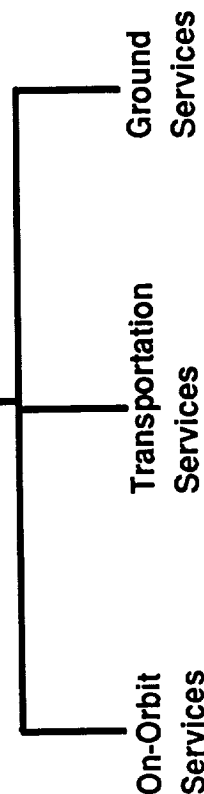
## Materials Processing - Ms. Kathryn Schmoll



## Earth & Ocean Observations - Dr. Shelby Tilford Mr. Charles Whitehurst



## Industrial Services - Dr. Earle Huckins

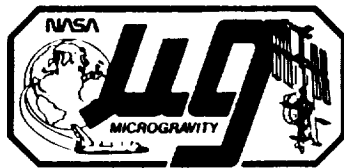




## MATERIALS PROCESSING IN SPACE (MPS) PANEL

- Ms. Kathryn Schmoll, NASA-HQ, briefed the Workshop on the Microgravity Science and Applications Division (MSAD) at NASA-HQ, the MPS panel Workshop goals, and identified the space experts assigned to the MPS sub-panels.
- Dr. William Oran, NASA-HQ, briefed the Workshop on commercial involvement in the space program and some of the mechanisms. Mr. Oran discussed the companies currently involved and the types of agreements available to be executed between NASA and industry.
- Mr. Charles Baugher, NASA-MSFC, briefed the Workshop on planned microgravity and materials processing facilities on-board the Space Station.

# **MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION NASA HEADQUARTERS**



**KATHRYN S. SCHMOLL**

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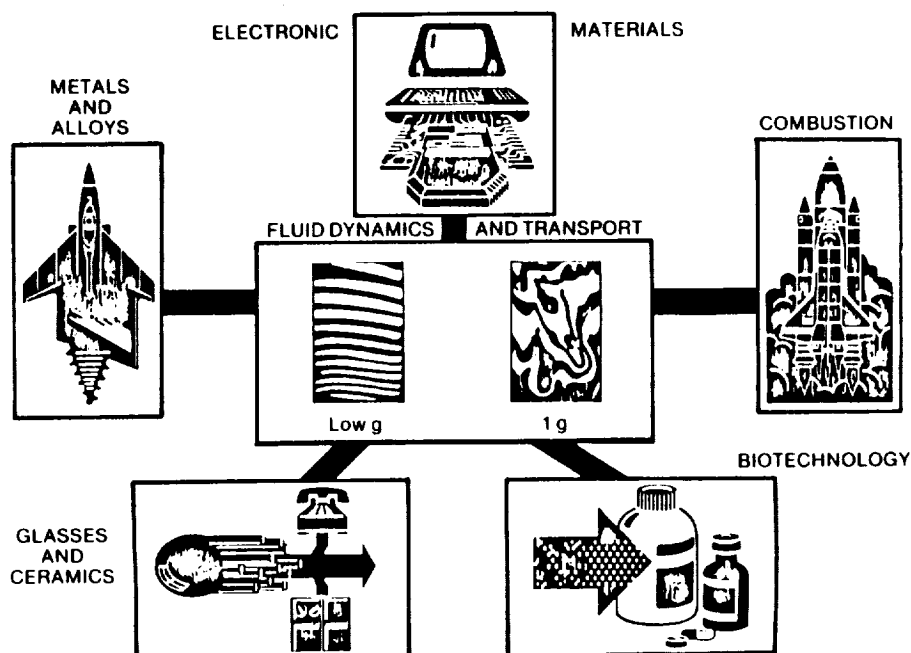
## **MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION**

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### **SPACE STATION WORKSHOP OBJECTIVES**

- **INFORM PRIVATE INDUSTRY ABOUT MATERIALS PROCESSING IN SPACE (MPS) AND PRESENT NASA RESEARCH PLANS FOR MPS TO FACILITATE CORPORATE PLANNING.**
- **GIVE PRIVATE INDUSTRY AN OPPORTUNITY TO PRESENT NASA WITH A FIRST-HAND VIEW OF TECHNOLOGICAL PROBLEMS, NEEDS AND INTERESTS IN THOSE INDUSTRIES THAT NORMALLY PRODUCE FOR THE INDUSTRIAL/COMMERCIAL MARKETPLACE.**
- **PROVIDE A FORUM FOR DISCUSSING AND MATCHING INDUSTRY TECHNOLOGICAL NEEDS WITH SPACE RESEARCH AND TECHNOLOGY PLANNING. IDENTIFY POTENTIAL AREAS OF COOPERATION BETWEEN INDUSTRY AND GOVERNMENT.**
- **ASSURE, THROUGH A REVIEW OF RESEARCH AREAS AND IMPLEMENTING EXPERIMENTS THAT APPROPRIATE SPACE STATION CAPABILITIES WILL BE PROVIDED TO SUPPORT COMMERCIAL USERS REQUIREMENTS.**
- **IDENTIFY KEY ISSUES.**
- **ESTABLISH CONTACTS FOR FUTURE COMMUNICATIONS OR NEGOTIATIONS BETWEEN INDUSTRY AND GOVERNMENT.**

# MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION



# MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION

## MICROGRAVITY SCIENCE AND APPLICATIONS DISCIPLINES

### FLUID DYNAMICS AND TRANSPORT PHENOMENA

- CRITICAL POINT PHENOMENA
- SURFACE BEHAVIOR
- CHEMICAL REACTION
- RELATIVITY
- TRANSPORT PHENOMENA
- SOLIDIFICATION MODELS

### GLASSES AND CERAMICS

- NEW GLASS COMPOSITIONS
- FINING
- SPHERICAL SHELLS
- NUCLEATION/CRYSTALLIZATION

### ELECTRONIC MATERIALS

- VAPOR GROWTH
- MELT GROWTH
- SOLUTION GROWTH
- FLOAT ZONE

### METALS AND ALLOYS

- MONOTECTICS
- EUTECTICS
- UNDERCOOLING
- SOLIDIFICATION FUNDAMENTALS
- THERMOPHYSICAL PROPERTIES

### BIOTECHNOLOGY

- NEW TECHNIQUE DEVELOPMENT
- EVALUATION OF CFES
- PROTEIN CRYSTAL GROWTH
- BIOREACTOR

### COMBUSTION SCIENCE

- SOLID SURFACE
- POOL BURNING
- PARTICLE CLOUD
- DROPLET BURNING



# **MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION**

## **MATERIALS PROCESSING SUBPANELS**

### **1.) BIOTECHNOLOGY SUBPANEL**

MR. D. CLIFFORD  
DR. C. BUGG  
DR. P. TODD  
DR. F. SALEMME  
DR. R. SNYDER

### **2.) ELECTRONIC MATERIALS SUBPANEL**

PROF. A. WITT  
DR. S. LEHOCZKY  
DR. K. BACHMANN  
DR. D. LARSON JR.  
MR. F. ROSENBERGER

### **3.) METALS & ALLOYS SUBPANEL**

DR. F. LEMKEY  
DR. R. NAUMANN  
DR. M. GLICKSMAN  
PROF. J. PEREPEZKO  
DR. T. WANG

### **4.) GLASSES & CERAMICS SUBPANEL**

DR. S. LEVINE  
MR. J. ETHRIDGE  
DR. G. NEILSON  
DR. M. LEE  
DR. P. MELLING  
MR. J. SALZMAN

### **5.) ORGANICS & POLYMER SUBPANEL**

DR. M. RUNGE  
MS. D. WEIKER  
DR. J. CARUTHERS  
DR. D. FRAZIER  
DR. L. TORRE  
DR. C. PODSIADLY

# **MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION**

## **MATERIALS PROCESSING PANEL JOINT WORKING SESSION**

**NOV 4**

2:00	KATY SCHMOLL	BRIEF INTRODUCTION
2:00-2:20	MARK LEE	CODE EN ACTIVITIES & PLANS FOR SPACE STATION
2:20-2:40	FRANZ ROSENBERGER	FLUIDS DISCUSSION
2:40-3:00	JACK SALZMAN	FLUID PHYSICS/ DYNAMICS FACILITY
3:00-3:20	SUKANT TRIPATHY	POLYMERS RESEARCH
3:20-9:00	INDIVIDUAL SUBPANEL SESSIONS	

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## **MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION**

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### **MATERIALS PROCESING PANEL JOINT WORKING SESSIONS (CONT.)**

#### **NOV 5**

8:15 - 11:00

INDIVIDUAL SUBPANEL SESSIONS

11:30 - 11:50

SUMMARY OF SUBPANEL PROGRESS

- RESEARCH AREAS
- EXPERIMENTS
- FACILITIES AND EQUIPMENT
- ISSUES AND REQUIREMENTS

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## **MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION**

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### **CONTACTS**

DR. ROBERT NAUMANN

DR. ROGER CROUCH

MS. MARY KICZA

MICRO GRAVITY SCIENCE AND  
APPLICATIONS DIVISION

NASA HEADQUARTERS  
CODE EN  
WASHINGTON, DC 20546  
(202) 453-1490

## **FY 1985 NASA GOAL (NO. 7)**

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### **EXPAND OPPORTUNITIES FOR U.S. PRIVATE SECTOR INVESTMENT AND INVOLVEMENT IN CIVIL SPACE AND SPACE-RELATED ACTIVITIES**

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#### **CENTERS FOR COMMERCIAL DEVELOPMENT OF SPACE**

##### **OBJECTIVES**

- PROVIDE A PATHWAY FOR U.S. INDUSTRY TO DEVELOP COMMERCIAL MARKETS USING THE ATTRIBUTES OF SPACE
  - NEW PRODUCTS
  - NEW SERVICES
  - NEW PROCESSES

##### **CRITERIA**

- CONSORTIA OF INDUSTRY/ACADEMIA/GOVERNMENT
- INDUSTRIALLY DRIVEN R&D
- COMMITMENT OF NON-NASA RESOURCES
  - SELF SUSTAINING IN 5 YEARS
- NASA FUNDS UP TO \$1M/YEAR/CCDS

## CENTERS FOR COMMERCIAL DEVELOPMENT OF SPACE

TECHNICAL DISCIPLINE	# INVOLVED	CCDS'S
1. Automation & Robotics	2	Univ. of Wisconsin, Madison, WI ERIM, Ann Arbor, MI
2. Life Sciences	3	Univ. of Colorado, Boulder, CO Penn State Univ., Univ. Park, PA Univ. of Alabama, Birmingham, AL
3. MPS	5	Battelle, Columbus, OH Univ. of Alabama, Huntsville, AL Vanderbilt Univ., Nashville, TN Clarkson Univ., Postdam, NY Univ. of Houston, Houston, TX
4. Remote Sensing	2	ITD, NSTL, MS. Ohio State, Columbus, OH
5. Space Power	2	Auburn Univ., Auburn, AL Texas A&M Univ., College Station, TX
6. Space Propulsion	1	Univ. of Tennessee Space Institute Tullahoma, TN
7. Space Structures & Materials	1	Case Western Reserve Univ. Cleveland, OH

**SUMMARY:** There are currently seven (7) Technology Disciplines represented in the CCDS program.  
The majority of the CCDS's are conducting research in materials processing in space (MPS).

IC-2025  
9/4/87

### NASA OFFICE OF COMMERCIAL PROGRAMS (OCP) Corporate Investment in Space-Related Research

#### Constraints

Lack of familiarity with space environment,  
unique attributes, commercial possibilities

Lack of sufficient technical data base

Lack of available experimental hardware

Entry costs can be high, lead times long

Government controlled transportation  
system



#### NASA Actions

Extensive awareness program and information  
dissemination

Centers for the Commercial Development of Space  
Space

NASA funded/industry supported R & D  
Enhancements

TEA's, IGI's, JEA's, SSDA's

National/NASA Commercial Uses of  
Space Policy

# NASA OFFICE OF COMMERCIAL PROGRAMS (OCP)

## Market Sectors

- **Communications**
- **Remote Sensing**
- **Life Sciences and Biotechnology**
- **Materials Processing in Space**
  - Crystal Growth
  - Metals and Alloys
  - Glasses and Ceramics
  - Combustion
- **Space Services and Infrastructure**
  - Facilities
  - Operations
  - Technology
    - + Power
    - + Propulsion
    - + Automation and Robotics

## COMMERCIAL DEVELOPMENT OF SPACE OPTIONS

JOINT EFFORT NEGOTIATED CASE-BY-CASE EACH PARTY PROVIDES RESOURCES FOR ITS PORTION OF EFFORT TERMS/CONDITIONS REFLECT RISK, INVOLVEMENT, INVESTMENT						
	GOVERNMENT FUNDED	TECHNICAL EXCHANGE	GUEST INVESTIGATOR	JOINT ENDEAVOR	SPACE SYSTEM DEVELOPMENT	LAUNCH SERVICE
	DATA AND RIGHTS IN PUBLIC DOMAIN	IND UTILIZES NASA GROUND-BASED RESEARCH CAPABILITY	IND SCIENTIST WORKS WITH NASA PRINCIPAL INVESTIGATOR	IND DEVELOPS NEED, MARKET, PROVIDES FLIGHT HARDWARE  NASA PROVIDES SHUTTLE SERVICES, TECHNICAL ASSISTANCE	NASA JUDGES LAUNCH AND INTEGRATION COST CAN BE PAID BACK  FIRST FLIGHT OF NEW INDUSTRY	IND PAYS ALL, NO GOVERNMENT SUPPORT
FUNDING						
SCIENTIST						
EXPERIMENT						
EQUIPMENT		NEGOTIABLE		NEGOTIABLE		
INTEGRATION AND LOW-G ENVIRONMENT						
DATA AND SAMPLES				NEGOTIABLE		
PROPRIETARY RIGHTS		NEGOTIABLE	NEGOTIABLE	NEGOTIABLE		

OCP-0916

The following seven charts have been updated to reflect the most current information. All other charts remain unaltered.

## COMMERCIAL DEVELOPMENT OF SPACE AGREEMENTS

<u>COMPANY</u>	<u>VENTURE</u>	<u>STATUS</u>
MDAC	ELECTROPHORESIS OPERATIONS IN SPACE	JEA SIGNED 1/80
DUPONT	RESEARCH ON CATALYTIC MATERIALS	TEA SIGNED 6/81 (EXPIRED)
INCO	RESEARCH ON ELECTROPLATING PROCESS	TEA SIGNED 8/81 (INACTIVE)
GTI CORPORATION	MATERIAL PROCESSING IN SPACE	JEA SIGNED 1/82
ARTHUR D. LITTLE, INC	MICROGRAVITY ON CERTAIN PROPERTIES OF STORED BLOOD	MOU SIGNED 1/83
HONEYWELL	RESEARCH ON HgCdTe CRYSTALS	TEA SIGNED 2/83
CINEMA 360 INC. (NON-PROFIT CONSORTIUM OF PLANETARIUMS)	FILMING OF IN FLIGHT STS ACTIVITIES (PRODUCTION OF SINGLE 30 MIN FILM)	JEA SIGNED 2/83

## COMMERCIAL DEVELOPMENT OF SPACE AGREEMENTS

<u>COMPANY</u>	<u>VENTURE</u>	<u>STATUS</u>
MICROGRAVITY RESEARCH ASSOCIATES	MPS EXPERIMENTS	JEA SIGNED 4/83
ORBITAL SCIENCES CORP.	TOS UPPER STAGE	COOPERATIVE AGREEMENT SIGNED 4/83
FAIRCHILD	DEVELOPMENT OF FREE-FLYING PLATFORM	JEA SIGNED 8/83
SPACECO LTD	INSTRUMENTATION FOR MEASUREMENT OF PAYLOAD ENVIRONMENT	JEA SIGNED 1984
COMMERCIAL CARGO SPACELINES	STS CARGO BOOKING SERVICE	MOU SIGNED 1/84
THRESHOLD CORP.	FILMING OF IN FLIGHT STS ACTIVITIES (PRODUCTION OF SINGLE 30 MIN FILM)	MOU SIGNED 4/84
DEERE & COMPANY	RESEARCH IN ALLOY FORMATION	TEA SIGNED 6/84

## COMMERCIAL DEVELOPMENT OF SPACE AGREEMENTS

<u>COMPANY</u>	<u>VENTURE</u>	<u>STATUS</u>
3M (2 YEARS)	RESEARCH IN ORGANIC AND POLYMER CHEMISTRY	JEA SIGNED 9/84
MARTIN MARIETTA CORP.	RESEARCH-EVALUATION OF FLUID DYNAMICS DATA AT ZERO-G	JEA SIGNED 10/84
ROCKWELL INTERNATIONAL	FLUIDS EXPERIMENT APPARATUS	MOU SIGNED 11/84
DEFENSE SYSTEMS, INC.	DATA RELAY SATELLITE	MOU SIGNED 12/84
BOEING	INDUSTRIAL SPACE PROCESSING RESEARCH PROGRAM	MOU SIGNED 2/85
GRUMMAN AEROSPACE CORPORATION	MPS FURNACE EXPERIMENTS	MOU SIGNED 2/85
TRANSPACE CARRIERS	PRIVATIZATION OF DELTA ELV	MOU SIGNED 5/85

## COMMERCIAL DEVELOPMENT OF SPACE AGREEMENTS

<u>COMPANY</u>	<u>VENTURE</u>	<u>STATUS</u>
INSTRUMENTS TECHNOLOGY ASSOCIATES	STANDARDIZED EXPERIMENTS CARRIER	JEA SIGNED 6/85
SPACE INDUSTRIES, INC.	INDUSTRIAL SPACE FACILITY	MOU SIGNED 8/85 SSDA SIGNED 8/85
SPERRY CORPORATION	MAGNETIC ISOLATION SYSTEM TO BUFFER MPS EXPERIMENT/HARDWARE AGAINST VIBRATIONS AND SHOCK	MOU SIGNED 8/85
GTE	ORGANIC AND POLYMERIC MICROGRAVITY GROWTH EXPERIMENTS	MOU SIGNED 9/85
SCOTT SCIENCE AND TECHNOLOGIES, INC.	RECOVERABLE UPPER STAGE LIQUID-PROPELLED VEHICLE (2K TO 19K LBS. TO GEO)	MOA SIGNED 10/85
3M (10 YEARS)	RESEARCH IN ORGANIC AND POLYMER CHEMISTRY	JEA SIGNED 12/85

## COMMERCIAL DEVELOPMENT OF SPACE AGREEMENTS

<u>COMPANY</u>	<u>VENTURE</u>	<u>STATUS</u>
INTERNATIONAL SPACE CORPORATION (ISC)	MPS HARDWARE AND EXPERIMENTS	JEA SIGNED 12/85
RANTEK	RESEARCH ON RHEUMATOID ARTHRITIS	MOU SIGNED 12/85
DAVID A. MOUAT	SATELLITE AND AIRCRAFT REMOTE SENSING FOR GEOBOTANY & MINERAL	TEA SIGNED 2/86
INSTITUTE FOR TECHNOLOGY DEVELOPMENT (ITD)	COMMERCIAL REMOTE SENSING TECHNOLOGY	MOA SIGNED 3/86
EARTHDATA CORPORATION	REMOTE SENSING TECHNOLOGY	TEA SIGNED 3/86
ABEX CORPORATION	MATERIAL PROCESSING IN LOW-G	TEA SIGNED 3/86
ROCKWELL CORPORATION	MATERIAL SCIENCE GROUND-BASED RESEARCH WITH MSFC	TEA SIGNED 4/86

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## COMMERCIAL DEVELOPMENT OF SPACE AGREEMENTS

<u>COMPANY</u>	<u>VENTURE</u>	<u>STATUS</u>
BOEING AEROSPACE COMPANY (BAC)	CRYSTAL GROWTH EXPERIMENTS ON THE SHUTTLE	JEA SIGNED 5/86
SPACE SERVICES, INC.	USE OF WALLOPS AS LAUNCH SITE FOR ELV OPERATIONS	MOA SIGNED 9/86
GENERAL SPACE CORP.	DEVELOPMENT OF A COMMERCIAL ORBITING POWER SOURCE	MOU SIGNED 10/86
HERCULES AEROSPACE	GROUND-BASED LOW-G EXPERIMENTS ON POLYMERIC MATERIAL - MSFC & LeRC	TEA 11/86
ROCKWELL CORPORATION	FLOATING ZONE CRYSTAL GROWTH RESEARCH IN LOW-G	JEA SIGNED 3/87
BOEING ELECTRONICS COMPANY	JOINT POLYMER RESEARCH W/ MSFC	TEA SIGNED 9/87
INSTRUMENTATION TECHNOLOGY ASSOCIATES, INC.	MATERIALS DISPERSION APPARATUS	MOU SIGNED 1/88



# CCDS Member Companies

ALCOA	E.I. du Pont de Nemours	KMS Fusion	Supelco, Inc.
Allied Signal	EG&G	Lemont Scientific Co.	Symbolics, Inc.
Alza	Elanex Pharmaceutical, Inc.	Lockheed Missiles & Space Co.	Synercom, Inc.
AMOCO Chemicals Corp.	Electroponc	Madison Kipp Corp.	TAM Ceramics, Inc.
Applied Info. Research Center	Engelhard Corp.	Martin Marietta Aerospace	Technion, Inc.
Arthur D. Little, Inc.	Entech, Inc.	Mass. Centers of Excellence Corp.	Teledyne Brown
ARMCO, Inc.	E-Systems, Inc.	Maxwell Laboratories	Engineering
Astronautics Corp. of America	Ethyl Corp.	McDonnell Douglas Corp.	Teledyne Wah
AT&T Bell Labs	Fairchild Space Systems	Merck, Sharp, and Dome	Chang Albany
Automated Systems	Feranti International Controls	Merck Pharmaceutical Co.	3M
AVX Corporation	Ford Aerospace, Inc.	Mickley & Assoc.	Trans-Temp
Ball Aerospace	Gammex	Monoclonal Production	TRW
Barnes Engineering	Gas Research Institute	OHMTEK, Inc.	UpJohn Company
Battelle-Columbus & Northwest	GE Space Systems, Inc.	Perkin-Elmer Corp.	Westinghouse
Beaver Dam Energy Growth	Gelman Sciences	Phyto Farms of America	Wyle Laboratories
Bell Aerospace Textron	General Dynamics Fort Worth	Pierson Products, Inc.	II-VI, Inc.
Boeing Aerospace Co.	General Electric Co.	Polomac Electric Power Co.	Zetachron
Boeing Electronics Co.	General Motors	PPG Industries, Inc.	
Burroughs-Wellcome Co.	GEO Decisions, Inc.	Precision Scientific	
Cabot Corporation	GEO Information Services	Proctor & Gamble	
CMA Furnaces, Inc.	Geospectra, Inc.	Quantum Technologies	
COMSAT Corp.	Goodyear	Rockelodyne	
Coulter Corp. (Epics Division)	Grumman Corp.	R.W. Teater & Assoc.	
Crystal Specialties, Inc.	GTE Sylvania	Rockwell International	
Compuserv	Gulf State Utilities	Rockwell Science Center	
DANTEC Electronics	Hercules, Inc.	Saturn Corp.	
Deere & Co.	Honeywell EOD	Schering Corp.	
Delco Remy	Honeywell Science & Technology	Scientific Enterprises	
Destek	Houston Astronautics, Inc.	Scientific Systems, Inc.	
Dow Chemicals	Hutson Chemical	Silicon Sensors	
Dow Corning	Instrumentation Technology Assoc.	Smith-Kline & Beckman Lab.	
Digene	International Imaging Systems	Snap On tools Corp.	
Duperon, Inc.	Invitron	Special Metals, Co.	
Eagle-Picher, Inc.	Johnson Controls, Inc.	Spectron Dev. Labs	
Edison Polymer Innovation Corp.	Kayex Corp.	Sperry Corp.	
		Sundstrand Corp.	

## OFFICE OF COMMERCIAL PROGRAMS

### FOREIGN INTERESTS IN COMMERCIAL USES OF SPACE

#### JAPAN

- LAUNCH VEHICLES
- COMMUNICATION SATELLITES & GROUND STATIONS
- MATERIALS PROCESSING LAB FOR SPACE STATION
- FREE FLYING MANUFACTURING PLATFORMS
- REMOTE SENSING SATELLITES

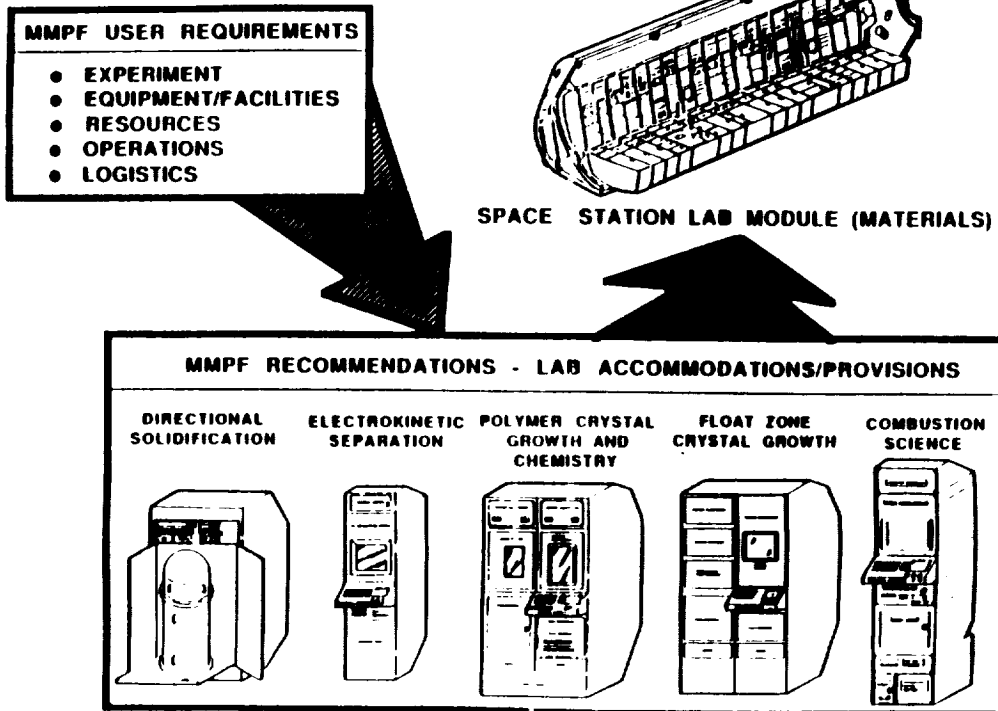
#### WEST GERMANY

- MATERIALS PROCESSING ON DEDICATED SPACE LAB FLIGHTS
- PRIME SUPPORTER FOR "COLUMBUS" MATERIALS PROCESSING LAB FOR SPACE STATION
- COMMUNICATIONS SATELLITES

#### FRANCE

- LAUNCH VEHICLES
- COMMUNICATIONS SATELLITES
- REMOTE SENSING SATELLITES
- FREE FLYING PLATFORMS
- MANNED REUSABLE "SHUTTLE"

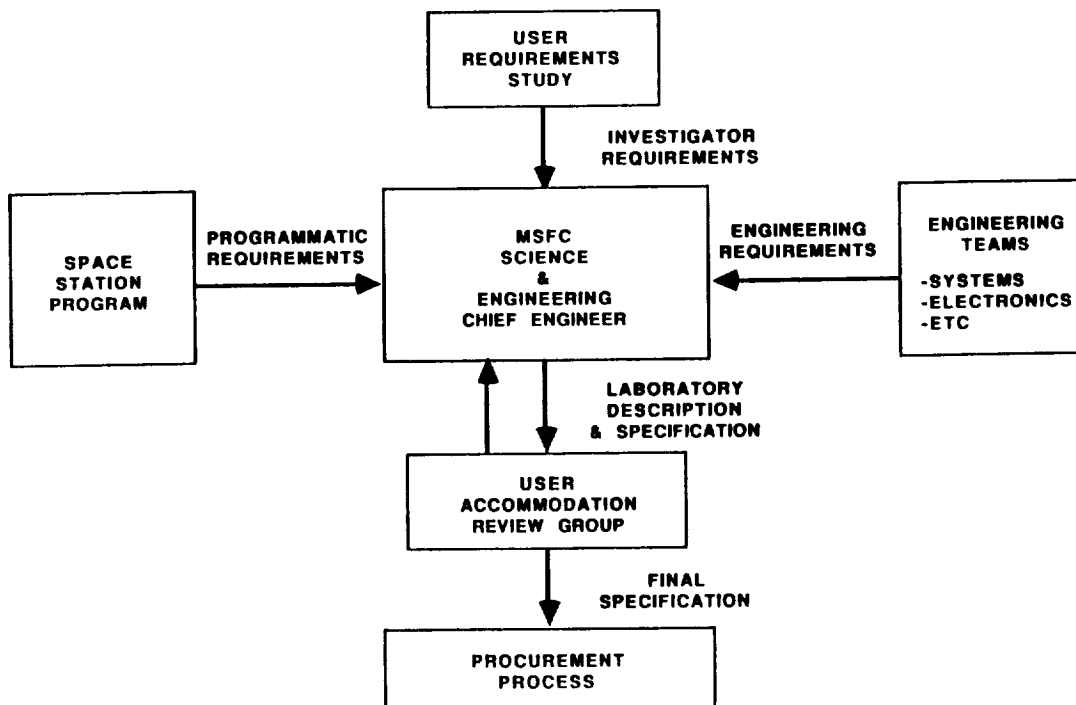
# THE MICROGRAVITY AND MATERIALS PROCESSING FACILITY (MMPF) STUDY



## EXPERIMENT FACILITIES IDENTIFIED FOR MMPF

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>● ACOUSTIC LEVITATOR</li> <li>● ALLOY SOLIDIFICATION</li> <li>● ATMOSPHERIC MICROPHYSICS</li> <li>● AUTOIGNITION FURNACE</li> <li>● BIOREACTOR/INCUBATOR</li> <li>● BRIDGMAN - LARGE</li> <li>● BRIDGMAN - SMALL</li> <li>● BULK CRYSTAL GROWTH</li> <li>● CONTINUOUS FLOW ELECTROPHORESIS</li> <li>● CRITICAL FLOW PHENOMENA</li> <li>● DROPLET/SPRAY BURNING</li> <li>● ELECTROEPTAXY</li> <li>● ELECTROSTATIC LEVITATOR</li> <li>● E.M LEVITATOR</li> <li>● FLOAT ZONE</li> </ul> | <ul style="list-style-type: none"> <li>● FLUID PHYSICS</li> <li>● FREE FLOAT</li> <li>● HIGH TEMPERATURE FURNACE</li> <li>● ISOELECTRIC FOCUSING</li> <li>● LATEX REACTOR</li> <li>● MEMBRANE PRODUCTION</li> <li>● OPTICAL FIBER PULLING</li> <li>● ORGANIC AND POLYMER CRYSTAL GROWTH</li> <li>● PREMIXED GAS COMBUSTION</li> <li>● PROTEIN CRYSTAL GROWTH</li> <li>● ROTATING SPHERICAL CONVECTION</li> <li>● SOLID SURFACE BURNING</li> <li>● SOLUTION CRYSTAL GROWTH</li> <li>● VAPOR CRYSTAL GROWTH</li> <li>● VARIABLE FLOW SHELL GENERATOR</li> </ul> |
|---|---|

## SPACE STATION ENGINEERING LABORATORY MODULE DESIGN



1-949-7

## SPACE STATION PROJECTS OFFICE LABORATORY MODULE

### LABORATORY SUBSYSTEMS

#### ● STRUCTURES

- SINGLE/DOUBLE RACKS
- FRONT PANELS
- STORAGE CONTAINERS
- SAFE LOCKERS
- MISC. SECOND. SUPP. STRUCT.

#### ● PROCESS MATERIALS MANAGEMENT

- GAS/LIQUID SEPARATORS
- WASTE CONTAINMENT/PURIFICATION/VENT SYSTEMS
- PLUMBING

#### ● FLUIDS/GASES

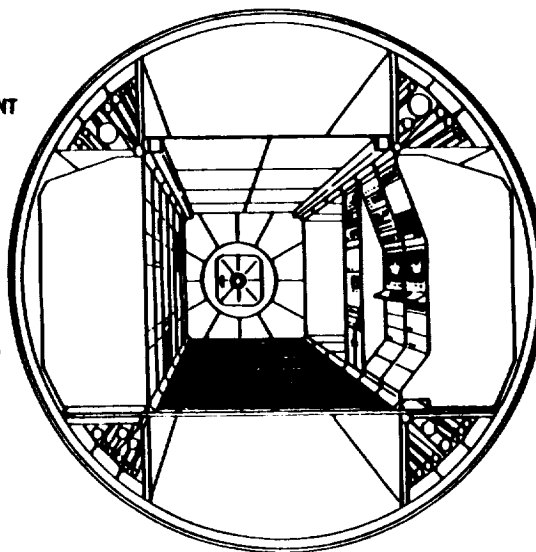
- GAS/LIQUID STORAGE VESSELS
- SENSORS/VALVES/PLUMBING
- ULTRAPURE WATER PROCESSING

#### ● VACUUM VENT

- TWO 6" VACUUM LINES
- SHUT-OFF VALVES
- PRESSURE SENSORS

#### ● ECLSS

- LIFE SUPPORT
- HANDWASH/EYEWASH
- SHOWER/COMMODE



#### ● THERMAL CONTROL

- 50 KW HEAT REJECTION CAPABILITY
- LIQUID-LIQUID HEAT EXCHANGERS
- PLUMBING

#### ● LAB SUPPORT EQUIPMENT

- FLUIDS GLOVE BOX
- PARTICULATE GLOVEBOX
- WORKBENCH
- REFRIGERATOR
- FREEZER

#### ● DATA MANAGEMENT

- PROCESSORS
- LOCAL CONTROLLERS
- PAYLOAD RECORDER

#### ● ELECTRICAL POWER

- 90 KW DISTRIBUTION
- CABLING
- PAYLOAD POWER CONTROL
- UNITS

#### ● AUDIO/VIDEO

- CAMERAS
- PROCESSORS/CONTROLLERS

## ENGINEERING RECOMMENDATIONS

### ● UTILITIES

- POWER (UP TO 15 KW/LOCATION)
- THERMAL (WATER AND FORCED AIR)
- VACUUM (THERMAL CONTROL AND ROUGHING)
- GASSES (AR, O<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>, He, N<sub>2</sub>)
- LIQUIDS (LN<sub>2</sub>, H<sub>2</sub>O)

### ● KEY SUBSYSTEMS

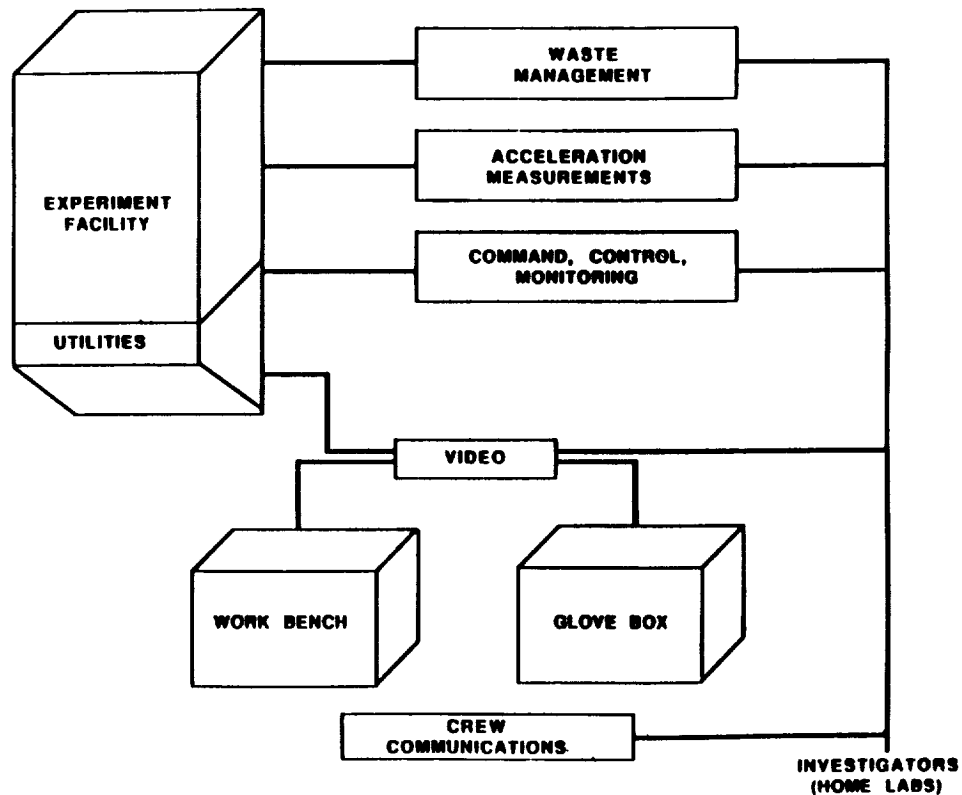
- ACCELERATION MONITORING (D. C. & LOW FREQUENCY)
- MATERIALS MANAGEMENT (WASTE COLLECTION & DISPOSAL)
- VIDEO (MANAGEMENT OF BANDWIDTH UTILIZATION)
- ELEMENT CONTROL WORKSTATION (EXPERIMENT MANAGEMENT)
- DATA MANAGEMENT AND SOFTWARE (REQUIRED SERVICES)
- WORKBENCH AND TOOLS
- GLOVEBOX WITH FLUID HANDLING CAPABILITY

### ● MAJOR OUTFITTING FACILITIES

- MICROSCOPE SYSTEM
- X-RAY SYSTEM
- CONTROLLED STORAGE (REFRIGERATOR AND FREEZER)
- EQUIPMENT WASHER/SANITIZER

1009.7-4D

## U. S. LABORATORY OPERATIONAL CONCEPT





## MATERIALS PROCESSING IN SPACE PANEL SUMMARY

### OPENING PLENARY SESSION

1. Ms. Kathryn Schmoll opened the Materials Processing in Space (MPS) Plenary session on Wednesday, November 4, 1987, by briefly introducing the plenary speakers and their topics of discussion. Dr. Mark Lee addressed NASA Code EN activities and plans for the Space Station. Dr. Franz Rosenberger presented basic fluid processes in microgravity. Mr. Jack Salzman then discussed Code EN plans for the Fluid Physics/Dynamics Facility in Space Station. Dr. Sukant Tripathy spoke on polymers research and potential applications in space.

2. Dr. Mark Lee addressed the Microgravity Science and Applications Division (MSAD) Program goals and Space Station activities plan. The Space Station objectives for electronic materials, biotechnology, combustion science, metals and alloys, fluid dynamics and mass transport, and glasses and ceramics areas were also covered. Science priorities for the six discipline working groups (DWG) in the above areas were outlined according to process, emerging technology and fundamental understanding.

3. Dr. Lee introduced the Microgravity and Materials Processing Facility (MMPF) studies and its link as a baseline working concept for MSAD requirements for Space Station.

4. Dr. Lee also displayed the strawman for the MSAD Space Station Reference Payloads, showing preliminary estimates of mass, volume, total average power and number of double racks for twenty of the thirty MMPF study facilities. A strawman for the six MSAD DWG Reference Payloads was also outlined.

5. After discussing the MSAD Space Station Planning Group, Dr. Lee defined and outlined, according to objective, approach and task management, the following nine Advanced Technology Development (ATD) areas:

- Noncontact temperature measurements;
- Interface measurements;
- Laser light scattering;
- Combustion/Fluid diagnostics;
- High resolution/high rate video;
- High temperature materials;
- High temperature furnace technology;
- Vibration isolation; and
- Biosensors.

6. In his fluids discussion, Dr. Rosenberger addressed the difficulty of measuring diffusion in liquids and the interference of convection in diffusion studies. He discussed the first microgravity results of the zinc and tin self-diffusion experiments from Ukanwa (Skylab 1973) and the temperature effect of self-diffusion in tin. For more information on the topic

Dr. Rosenberger suggests reading Fluid Sciences and Materials Science in Space, a book by the European Space Agency (ESA).

7. Mr. Salzman discussed the relevant applications/processes of fluids in the MPS sub-panels, such as testing of fundamental hypothesis/theories and measurement of thermo-physical properties. Mr. Salzman also discussed: the categories defined by the fluid dynamics and transport discipline working groups that outline the range of the fluid physics/dynamics experiments and importantly, how to provide accommodations aboard the Space Station to enable a wide variety of basic and applied research required by the fluids community.

8. Mr. Salzman also outlined a design approach for the fluid physics/dynamics facility with suggestions to identify user requirements, conduct trade studies to accommodate user requirements, select a concept, and define a development plan (cost, schedule, etc.). Additionally, Mr. Salzman defined the Reference Experiment Sets, which are discrete modules in various research areas, and discussed specifications of the Reference Set functional requirements.

9. In the polymers research area, Dr. Sukant Tripathy presented topics such as linear vs. non-linear optical response, unique electronic phenomenon, potential of all-optical devices, and reasons for organic polymeric materials.

10. The MPS panel broke into the following five sub-panels and one "quasi sub-panel", Combustion, to conduct working sessions in:

- Biotechnology, Separation, Purification;
- Electronic Materials;
- Metals and Alloys;
- Polymers;
- Glasses and Ceramics; and
- Combustion.

## MPS SUB-PANEL DISCUSSION SUMMARIES

### BIOTECHNOLOGY SUB-PANEL DISCUSSION SUMMARY

Biotechnology Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Robert Snyder		NASA/MSFC/ES76
Charlie Bugg	Director, Center for	Univ. of Alabama,
	Macromolecular Crystalliz.	Birmingham
Don Clifford	Mgr, Program Engineering	MDAC-STL
Paul Todd		Penn State Univ.
David Hyink	Senior Scientist	Weyerhaeuser Co.

Jim Cullor		Monoclonal Prod. Int'l Univ. of Calif. @ Davis
Lisa Mann	Applications Project Manager	Sterling Software NASA/Ames Res. Ctr.
John Berryman	Assoc. Director	Bioserve Space Technologies
Don Purdy	Program Manager	MDAC - St. Louis
Jim Van Alstine		USRA/NASA-MSFC
Gary Casuccio	General Manager	Energy Technology Cons.
Peter Ahlf	Engineer	MDAC - Wash., D.C.
Charles Baugher		NASA/MSFC
Ray Whitten	Dir., Commercial Development Div.	NASA/HQCC
Robert O. McBrayer	Mission Mgr - IML, USML	NASA/MSFC
Lee Vittitow	Dir., Aerospace Environ. Systems Division	McCoy & McCoy, Inc.
Tom Mahoney	Staff Officer	Nat'l Research Council
Andreas Plaas-Link		INTOSPACE, GmbH
Keith Gale	Engineer	Wespace

1. The Biotechnology sub-panel did not develop any new ideas for Biotechnology experiments in space, but concentrated their discussions on requirements and facility needs. The sub-panel agreed with the modular facility approach for the Space Station and the Advanced Development Program, but felt the latter is under-funded for the amount of work to be done, especially in biotechnology. The following section summarizes the Biotechnology sub-panel's discussions on the Space Station facility issues and other business issues.

2. The sub-panel suggested the emphasis with regard to the Space Station facility issues should be on requirements rather than on individual facilities. The first facility issue discussed pertained to the study of macromolecular crystallization, aggregation, synthesis, and assembly. Previous proposals for synthesis of macromolecules, or solid phase synthesis, were disapproved because of the difficulty in showing how gravity is involved in the folding of proteins when considering the force of gravity in fluids. Dimensional analysis indicates that the dimension of protein is so small that these dimensionless numbers show there is zero role of gravity. The sub-panel recommends studies of macromolecular crystallization, aggregation, synthesis, and assembly be initiated to carry the biotechnology issue into the 21st century.

3. The second facility issue was in the area of cellular level studies; secretion, multiplication, interaction, and differentiation. These terms evolved from a discussion in cell culturing, cell sustenance, and nutrition, which, in turn, immediately brought up the topic of a bioreactor. Since the Space Station facility issues were being viewed in terms of requirements and not individual facilities, it was suggested to stay away from the term "bioreactor".

4. The third Space Station facility issue discussed was the separation, purification, and fractionation of particles and (macro) molecules. This implies that the facility needs to



provide a range of techniques such as continuous flow electrophoresis, isoelectric focusing, isotachopheresis, and generic fluids equipment and other innovative approaches.

5. The fourth facility issue focussed on having integrated analytical systems onboard the Space Station: (macro)molecules, chemical products, and cells. The sub-panel agreed that from a requirements point of view, this allows the same specificity of pH and temperature to be made, and allows for better equipment integration and less chance for equipment duplication. The sub-panel further suggested that the integrated analytical systems should be left open-ended to vary modules as requirements change.

6. The fifth facility issue dealt with essential support: waste handling, sterilization, environmental health and safety, water quality and quantity. The sub-panel agreed that synthesis will require waste treatment and that some integrated system of waste disposal must be considered. Furthermore, water quality and quantity were considered especially essential support items and noted that many people do not realize how much water is used in a biological laboratory -- "a half pint just won't do".

7. The sub-panel also discussed several business issues. Recognizing that a distinction exists between commercial incentives and science incentives, the sub-panel labeled the first area under business issues as "incentives". The first incentive addressed was the National Space Biotechnology Laboratory concept. The sub-panel agreed that the Space Station should be regarded not as a "space station", but rather, as a national laboratory that by accident happens to be in space. Like the Oak Ridge Laboratory, it should be a place for basic and applied research with the intentions of learning something and not necessarily to produce anything. It should be a laboratory, with the need of humans to conduct experiments and research, and not a factory. The sub-panel also discussed the following incentives:

- Tax incentives;
- Protection of proprietary rights for existing space technology and future technological gains from space research;
- Getting early FDA participation to help bring a space product at least to the head of the queue;
- The technical advantages through cooperative research activities;
- Multi-discipline research and marketing opportunities via NASA-related companies; and
- The incentive to spread the risk, which is the whole purpose of research.

8. The second business issue was that of new proposals with innovation through the Centers for the Commercial Development of Space (CCDS). Each CCDS should provide a more open channel for potential users of the Space Station, acting as an avenue, on a continuous basis, for bringing in new research ideas and requirements.

9. The third issue represented a critique of new ideas. The sub-panel stated that the advances in the status of "biotechnology" and the "biotechnology community" needs in the Space Station era cannot be accurately estimated. The biotechnology area is rapidly growing, changing and evolving and it is difficult to plan experiments 7-8 years in advance. It is important that the laboratory be able to accommodate changes. The sub-panel thinks





that they will, hopefully, be able to identify diagnostic capabilities, generic research techniques, and theories, etc.

## METALS AND ALLOYS SUB-PANEL DISCUSSION SUMMARY

### Metals and Alloys Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
David Nye Donovan		Roberts Assoc. Inc.
John Perepezko	Professor	Univ. of Wisconsin
Judith Robey		NASA/JPL
William Hofmeister		Vanderbilt CCDS
Heinz Sprenger	Scientific Mkt Mgr	INTOSPACE
Gerald Scott	Sr. Scientist	ALCOA
Michael P. Anderson	Sr. Staff Physicist	Exxon
Chris Laszlo	Sr. Consultant	Braxton Associates
Richard Scotti	Executive Scientist	ORI
Frank Lemkey	Sr. Consulting Scientist	United Tech Rec Ctr
Robert A. Hall	Mgr, Space Sta Projects	Wyle Laboratories
Won-Kyu Rhim		JPL
Amber Dalley	Research Scientist	Energy Technology Cons.
Richard Lanam	Technical Ops Mgr	Engelhard Corp
Gerald Centanni	General Manager	Engelhard Corp
Greg Jenkins	Engineer	Teledyne Brown Eng.
Robert J. Bayuzick	Director	Vanderbilt Univ. Cntr for Space Proc. Eng. Mtls.
Donald Morel	Mgr, Mtls Research	Abex Research Center
Taylor Wang	Pgm Mgr, Microgravity Sci. & Appl.	JPL

1. Studying alloys under orbit conditions imposes numerous restrictions on the scope of research that can be conducted and the techniques and instruments that can be employed to measure various properties. The rationale and objective for conducting meaningful, world class research in the space environment was discussed by Professor M. Glicksman (RPI) in a lead off address to approximately 25 participants equally divided between industrial and NASA/Academic affiliations. A recommendation was made to look to new ways of managing experiments in controlled furnaces to minimize time of crew participation. The search for knowledge, e.g., influence on critical point phenomena, may itself be regarded as a justification for microgravity materials processing (see Fig. 1).

2. Overviews of previous experiments in microgravity and the competitive activities of the Russian, European, Japanese and Chinese scientists were provided by Dr. R. Naumann (NASA Huntsville) and F. Lemkey (United Technologies Research Center). The data base being generated by USSR's increasing time in the microgravity environment cannot be matched by NASA. Avenues toward achieving additional flights and shared data bases with other space organizations in the world community should be encouraged.



3. The evolving furnace and containerless processing facilities were discussed by Dr. A. Lehoczky (NASA Huntsville) and T. Wang (JPL) respectively. The size, type, temperature, power and data acquisition/transmission requirements for furnaces on space station are still evolving. Inert waste gases cannot be vented and toxic gases require exceptional handling. Industry is seeking 2000°C+ temperatures; the present 1500°C is not good enough. The possible use of solar imaging furnaces was suggested. The importance of a pure clean environment for containerless processing was emphasized. More input from industry on these facilities was solicited.

3. Discussion of contactless measurements was provided by Dr. Mark Lee (NASA Headquarters). The results of a NASA workshop held in April on this subject were announced to become available shortly after this meeting. Techniques discussed included monochromatic pyrometry, laser spectroscopy (CARS), and rapid response pyrometry. The primary areas of contactless temperature measurements will be in the areas of containerless processing, fluids and combustion, and drop tower modeling experiments. JPL will be the lead center for this activity.

4. Dr. David Larson (Grumman) reviewed his company's furnace development program and flight experiences with NASA with respect to magnetic alloy processing under a JEA. Grumman's extensive time differences required to obtain an agreement with NASA were contrasted to the more rapid agreement experience of 3M reported previously at the workshop. Jim Fountain (NASA Huntsville) briefly reviewed the avenues of industrial participation including ISF and the microgravity research centers at NASA field facilities.

5. A highlight of the meeting was the open discussion of potential experiments and ongoing interests of the industrial participants stimulated by Professor John Perepezko's overview of the Metals and Alloys Strategic Plan. The generation of novel porous foams and hollow spheres was of interest to ALCOA and YIN Industries. Precious metal catalysts of controlled high surface areas and tailored porosities produced by containerless techniques were suggested by representatives of Engelhard Industries and ABEX. Interest also was shown in achieving more uniform distributions of composite dispersions through the proper control of wetting behavior in the microgravity environment. Purification of high value metals through melt processing (Engelhard) as well as on-line characterization of physical properties (Energy Technology Consultants) were suggested as fruitful areas of future industrial participation.

## POLYMERS SUB-PANEL DISCUSSION SUMMARY

### Polymers Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Larry P. Torre	Specialist Engineer	Boeing
Jim Caruthers		Purdue University
Deborah Weiker		Hercules Resrch Ctr
Venkat Raman	Mgr New Tech Mktg	Air Products & Chemicals

Willy Balaba	Sr. Scientist	ALCOA
Jeffrey Edwards	Space Marketing	Hercules Aerospace
Michael Runge	Research Mgr	3M Co.
Jack Knox	Sr. Res. Associate	Amoco Chemical Co.
Andreas Plaas-Link		INTOSPACE
Charles A. Lundquist	Director, CMDS	U of ALA, Huntsville
Daniel M. Blake		SERI
Sukant Tripathy		Univ. of Lowell
Jon Geibel		Phillips Petroleum
Tom Bannister	Sr. Staff Engineer	Wyle Laboratories
Jimmy R. Watkins		NASA/MSFC
Ray A. Cull	R&D Bus Devel.	Dow Corning
A.J. Schwoeble	Project Mgr	Energy Technology Cons.
Donald O. Frazier		NASA/OIC
Chris Podsiadly		3M
Bill Oran		NASA/HQ

1. The existing data base for polymer science and processing in microgravity is limited at best. Industrial involvement in microgravity polymer science will continue to be marginal until data is generated which stimulates interest. The goal of the Polymers sub-panel was to develop several concepts for polymer experiments. The experiments would be of industrial interest and would generate an initial data base with the potential for promoting increased interest. The Polymer Session consisted of approximately twenty participants (3 NASA, 2 Academic, 8 Material's Industry, 2 Aerospace, 5 Other). A pre-workshop meeting was conducted on Oct 8, 1987 in which the sub-panel agenda was set and developed some initial proposals for NASA to consider regarding the development of polymer MPS and commercial interest.

2. During the working sessions, the sub-panel generated approximately fifteen concepts for experiments. These concepts were discussed and narrowed down to four. These four were considered to be of the broadest interest to the industries represented and were considered to be of potential interest to other industries (not represented). The four potential concepts were:

- **Extensional Viscosity Of Polymeric Fluids** - These measurements currently cannot be made on earth because gravity causes the fluids to flow. The extensional viscosity has potential application to drop break-up in ink jet printing and to the pulling of molten polymers in fiber formation.
- **Copolymerization of Monomers with Varying Reactivity Ratios** - The object of this experiment would be to explore the effects of microgravity on local mixing. The polymers sequence distribution of the comonomer will be measured as a function of composition and the reactivity ratio.
- **Spinodal Decomposition** - Interest here is related to polymer blends and gaining information about the instability region in a phase transition from the mixed state to the formation of separate domains.

- **Foam Formation** - The object of this experiment would be to form a foam in the microgravity environment to determine if a more uniform cell geometry could be developed. It is expected that the drainage from the cell walls would be reduced. If the cell structure was influenced toward regularity then failure mechanisms could be studied and possibly related to the foam structure.
3. The above are preliminary concepts for experiments and require further definition before they are considered to be fully developed and without technical flaws. The extensional viscosity experiment has received the most conceptional planning of the four proposals. The copolymerization experiment would be investigated in a few weeks to determine its relative merit. The other two experiments were considered to require substantially more effort to develop their commercial potential.
4. The panel presented the four experiments to NASA, Dr. Robert Naumann. The experiments were well received and Dr. Naumann agreed to champion this approach to Mr. Jim Rose, Director of the NASA-HQ Office of Commercial Programs. Mr. Mike Runge of 3M has agreed to act as the focal point for the panel and NASA in the follow-up activities, including recommending potential team members to design and work the experiments, identifying required NASA participation, and recommendations concerning the experiment facilities to be built, leased or borrowed.
5. The sub-panel made two other specific recommendations to NASA:
- The Fluid Physics group in the NASA microgravity community should look at non-Newtonian fluids (e.g., solutions of polymers) rather than ideal Newtonian fluids; and
  - The existing polymer MPS experiments presently waiting for flight opportunities should be given further NASA consideration in the flight manifesting to be flown as soon as possible in order to support a timely development of the basic polymer MPS database.
6. The NASA Code EN/MSAD people were enthusiastic and supportive of the sub-panel's recommendations and proposals.



## COMBUSTION SUB-PANEL DISCUSSION SUMMARY

### Combustion Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Bruce Peters	Engineer	General Motors Res. Lab
Jim Hansel		Air Prod. & Chemicals, Inc.
Kenneth Maloney		Phillip Morris, USA
Kurt Sacksteder		NASA Lewis Research Center

1. The first several hours of the Combustion sub-panel working session consisted of a tutorial on microgravity combustion, including summaries of the technical advantages of performing research in low gravity, the current NASA program in combustion, and particular technical results that have been obtained. Considerable discussion occurred during this portion of the meeting to clarify, for those panel members new to microgravity combustion, the unexpected results that have been obtained in many of the program experiments. Of particular interest were the experiments in solid surface flame spreading, premixed gas flames, and droplet combustion. It was clearly agreed that much of the true value of the research proceeded from the unexpected results obtained for what, in normal gravity, is considered to be a very fundamental process. From this discussion the conclusion was reached that the best inducement that NASA can provide (to industry) in this area is a base of fundamental understanding of low-gravity phenomena that will inspire innovative ideas.

2. The basic concepts currently envisioned for the Space Station Modular Combustion Facility (MCF) were reviewed, including the reasons for the concept of modularity, the rationale for determining the complement of common equipment to be included, and the list of reference experiments to be used to determine facility accommodation requirements and common equipment. The discussion focused upon the completeness of the list of reference experiments, and a suggestion was made to add a reference experiment in the area of metals combustion. Dr. Jim Hansel and Dr. Kenneth Maloney agreed to provide a first order estimate of the experiment specifications.

3. Additional discussion also focused upon the likely design drivers for the MCF. While it is agreed that quite a lot of tradeoff study work will be required to understand the drivers, at the current time one clear driver is seen to be the throughput of consumables: fuel, oxidizer and diluent gases, and the products of combustion processes. Since the simple venting of combustion products seems to be an unlikely eventuality, the suggestion was made to encourage NASA to support the development of combustion product recycling technology, such as "membrane separation technology".

4. In the concluding discussions, the principal concerns focussed on how the requirements identified for Space Station combustion research will be included in the laboratory module specifications and how the industrial combustion research community will be able to review the status of those requirements.



## ELECTRONIC MATERIALS SUB-PANEL DISCUSSION SUMMARY

Electronic Materials Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Ray Yoel	Engineer	USRA/NASA/MSFC
Amber Dalley	Metallurgist	Energy Technology Consultants
Richard Scotti	Scientist	ORI
Franz Rosenberger	Professor/Director	UAH CMMR
Dave Larson	Sr. Staff Scientist	Grumman Corp.
J.A. Ralph	Engineer	ISC - Melbourne
S.L. Lehoczký	Chief, Crystal Growth Branch	NASA/MSFC-ES 75
John Viola	Program Manager	Rockwell Science Ctr
Trip Mookherji		Teledyne Brown
Ludwig Van Den Berg		EG&G
Bruce Whitehead	Staff Scientist	Honeywell
Anthony B. Hmelo	Professor	SUNY Stony Brook
Dave Lind	MTS	Rockwell Int. Corp.
David Yoel		Boeing
Gus Witt	Professor	MIT
Klaus J. Bachmann		North Carolina State U.
Ronald F. Paulson	VP, EO Technology	EDO Corp/Barnes
		Engineering
C.B. May	Program Manager	MDAC-Huntsville, AL
		Summary Data to come

1. The Electronic Materials sub-panel discussions related directly to Space Shuttle activities rather than Space Station activities since that facility is, by approximately one decade, removed from use. The sub-panel generated the following conclusions and recommendations (not in priority order):

- There was unanimous support and request for the establishment of powered free fliers.
- Strong support was expressed for a SURF facility. In it, memory effects under conditions of vapor deposition and molecular beam epitaxy are avoided. They limit, at this time, the realization of high resolution heterostructures with well controlled opto-electronic properties.
- It is considered mandatory that time in space be increased so as to keep space processing activity viable.
- Considering the paramount importance for exhaustive characterization of space processed materials, it is recommended to create a "National Special Characterization Facility".

2. The sub-panel expressed the following points of concern:

- Peer review procedures currently used are suspect - it is recommended that an internal review procedure be adopted. Related, a more rigorous research review and hardware analysis procedure should be adopted.
- Research funding for industry should be dealt with as a separate unit and proposals should not be considered competitive with those from academia.
- Efforts should be made to facilitate participation of "small business" in the space program (its needs are special).
- JEA processing procedures are excessively time consuming and discourage rather than encourage industry participation.
- CCDS's operate adequately for some needs, not so well for some others. Problems arise because of the characteristics of "academic research". (The verdict on the usefulness of CCDS's is not in as yet)

**GLASSES AND CERAMICS SUB-PANEL DISCUSSION SUMMARY**

Glasses and Ceramics Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Jack Salzman		NASA-LeRC
Mark Lee		NASA/Hq-EN
Tom O'Holleran		KMS Fusion
Peter Melling		Battelle
Gary Casuccio	General Mgr	Energy Technology Cons.
Tom Whalen	Prin. Res. Scientist	Ford Motor Co.
Venkat Raman	Mgr, New Tech Mktg	Air Products & Chemicals
Ronald F. Paulson	VP, EO Technology	EDO/Barnes
Roger Chassay	Dep Mgr, Micrograv Projects	NASA/MSFC
Jim Fountain		NASA/MSFC/PS05
MaryJo B. Meyer		NASA-LeRC
George Neilson		JPL
Heinz Sprenger	Scientific Mkt Mgr	Intospace
Ed Ethridge		NASA/MSFC

1. The glasses and ceramics sub-panel discussed the need for basic scientific research in glass fiber pulling. Some theoretical mathematical analysis of feasibility at the Jet Propulsion Laboratory shows that extrusion may be required to avoid "necking" (breaking



off). The sub-panel felt that there is some industry interest as a possible topic for joint effort with fluids research. The sub-panel concluded that industrial interest cannot realistically be expected until the basic research is conducted and some success is demonstrated.

2. The sub-panel felt that more narrowly focused research was required and is looking for input from more industries. The sub-panel manager suggests NASA send a mailing to the glass and ceramics industry telling about current research -- let industry think it over, and call them. The annual meeting of the Glass/Ceramics society may provide a reasonably good framework for future discussions.

3. The sub-panel discussed potential slip casting in microgravity experiments. Ford Motor Co.'s slip cast turbine blades had problems unrelated to the gravitational field. Basic research in order/disorder phenomena is currently funded by NASA Lewis Research Center. The sub-panel concluded that fundamental understanding of order/disorder phenomena may help problems like those of Ford Motor Co.

4. The sub-panel discussed the availability of glove boxes/powder pressing equipment onboard the Space Station. The sub-panel was concerned about hardware on the Space Station, particularly about the limited glove box facilities, the clean-up capability, and back-up resources. The sub-panel expressed the desire for replaceable modules so that glove box down-time will be minimized. Some sub-panel members indicated an interest in six glove boxes as back-ups. The uniaxial powder press was deemed to be helpful. The sub-panel concluded that a glove box dedicated to materials science is a "wished-for" entity on the space station and the powder press is not important in the early stages of the station.

5. The sub-panel expressed concern about who would be responsible for waste handling (experimenter or Space Station), and what limitations would be made on toxic materials and pressurized vessels. Complaints surfaced that the "proof-of-concept" that an experiment is safe against every conceivable hazard drastically prolongs the experiment preparation time. No suggestion was made for alternate procedures. The sub-panel identified Vanadium powder and Beryllium Fluoride as examples of toxic materials which may be used. The sub-panel was also concerned about waste segregation. The toxic materials to be segregated include liquids, gases, solids, and dry particulates. Non-toxic materials are liquids, gases, and solids. The sub-panel concluded that more industry-NASA discussion is needed to resolve these issues.

6. The sub-panel discussed chemical vapor deposition and sputtering (coating studies). Coating studies are of interest to the fusion pellet industry. The sub-panel members also recalled that CVD of diamond films on a substrate is of interest to electronic industry for dielectric properties, thermal conductivity, use as a high temperature semi-conductor, and resistance to damage from radiation environments. The sub-panel recommends that the fluid physics team encompass these aspects of microgravity research into their work.

7. The sub-panel discussed the accessibility of space experiments by researchers. Some compromise needs to be made between rapid sample retrieval and on board characterization studies. The availability of a Scanning Electron Microscope (SEM) was discussed. An on-board SEM with X-ray fluorescence for rapid experiment analysis and





decision on the next experiment is required. The equipment volume, weight, power, and data transmission impact needs to be studied. Concern was expressed that lengthy delays between performance of experiment and data collection would both interfere with the course of science and cause wasted time. The sub-panel concluded that unless reliable and frequent sample retrieval is available, additional risk space on the Space Station will have to be dedicated for generic characterization equipment.

8. The sub-panel discussed fuel targets for inertial confinements fusion studies. Presently there is uncertainty whether targets will need to be polymeric or glass. They will however, be complicated, multi-layer spheres. Foam spheres were also mentioned as a possibility. The current activity in fusion research requires few targets; instigation of a pilot plant would require manufacturing capabilities now undeveloped. Tritium, a volatile substance, is involved at some stage in manufacturing processes. If done on earth, this complication could be avoided, but manufacturing steps must planned. The sub-panel concluded that present needs can be met on the ground. Future needs may dictate tens of thousands of targets produced on an hourly basis. The sub-panel recommends that the large scale space production of glass and polymer spheres be investigated. Chemical vapor deposition coating studies are of interest; they may be handled by the fluid physics team.

## **MATERIAL PROCESSING IN SPACE CLOSING PLENARY SESSION**

1. During the wrap-up session the sub-panel chairmen reported their results to the panel chairman. The following issues were consistent through-out the sub-panel discussions:

- Need for precursor experiments;
- Access to space;
- Proprietary rights;
- Trade-offs between onboard analysis vs. quick return to Earth;
- Need for NASA support to industrial research up-front, especially with small companies;
- Need for data base of unexpected phenomenon of results;
- JEA processing;
- Tax incentives; and
- Operational concerns - onboard analysis and systems safety.

2. The Polymers sub-panel report included four proposed basic polymer MPS experiments and two recommendations. The experiments consist of:

- Extensional Viscosity Measurements in microgravity;
- Basic Polymerization Reaction in diffusion controlled environment;
- Spinodal Decomposition; and
- Structural Foam Production.

and the panel recommended:

- The existing polymer MPS experiments be flown.
- The NASA fluid physics discipline group to do experiments in non-Newtonian fluids, polymer fluids, and solutions to study:
  - Drop Break-Up
  - Drop Coalescence

3. The Metals and Alloys sub-panel reported the requirement for a high temperature (>2000°) furnace facility. The sub-panel expressed interest in five areas of research:

- Porous Foam - Hollow Spheres
- Composite Alloys - Wetting
- Precious Metal Catalysts
- Melt Purification
- Metals and Alloys Characterization

4. The Biotechnology sub-panel report recommended placing the emphasis on requirements rather than on individual facilities. The requirements include:

- the study of macromolecular crystallization aggregation, synthesis and assembly;
- cellular level studies;
- secretion, multiplication, interaction, and differentiation;
- separation, purification, and fractionation of particles and (macro)molecules
- integrated analytical systems for: (macro) molecules, chemical products and cells; and
- essential support such as:
  - waste handling sterilization,
  - environmental health and safety, and
  - water quality and quantity.

5. The Biotechnology sub-panel also discussed several other important business issues such as the National Space Biotechnology Laboratory concept, the need for early FDA participation in space processing experiments, technical advantages gained through cooperative research activities, and multi-discipline research and marketing opportunities via NASA-related companies.

6. The Combustion sub-panel report included the following conclusions and concerns:

- NASA's role in commercial developments in combustion is to provide a substantial data base of fundamental phenomena from which unexpected results will appear.
- The modular combustion facility approach to Space Station combustion research is appropriate.



- The consumables flow through - supplies of consumable gases and disposition of wastes - will be the principal driver for station combustion experiments.
- The sub-panel was concerned as to how the concepts and requirements for the modular combustion facility will be included in the data base, and how the data base will be periodically made available to academic and industrial researchers for review and update.

7. The Glasses and Ceramics sub-panel report consisted of technical concerns and business issues and obstacles. The sub-panel's technical concerns are gaps in the science base and hardware capabilities. The glasses research area currently has gaps in the science base with respect to fiber pulling (an equipment gap), phase separation, and hollow-sphere formation. The ceramics area faces an equipment gap in fiber growth via float zone research. The sub-panel identified the following as issues and obstacles facing commercialization opportunities in this area:

- Flight opportunities;
- Foggy understanding of participating in the MPS program;
- Insufficient industry participation in setting science and equipment priorities; and
- Timeliness from idea to flight given concerns about toxicity, particles, pressure vessels, and process of implementing was also discussed.





## EARTH AND OCEAN OBSERVATION PANEL

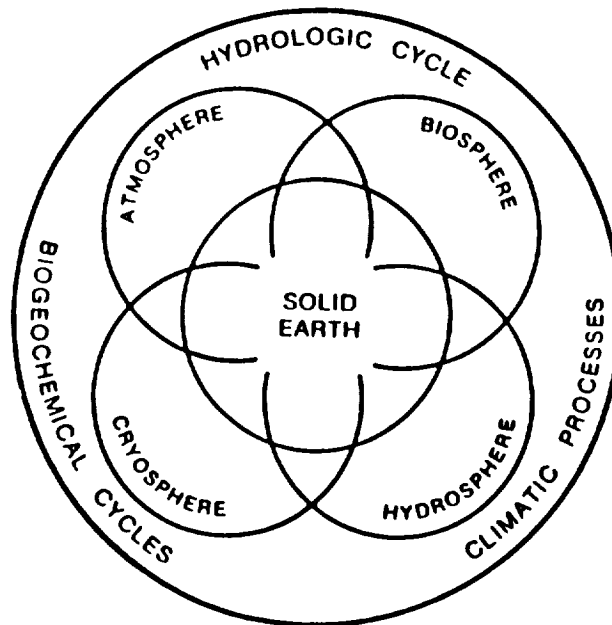
Dr. Shelby Tilford provided the Workshop with an overview of the Earth Observing System (EOS). Dr. Tilford discussed:

- The EOS concept;
- EOS instrumentation;
- Types of investigations;
- EOS program milestones and schedules;
- EOS baseline technical parameters; and
- The major earth sciences goals which EOS could help accomplish.



# EARTH OBSERVING SYSTEM

DR. SHELBY G. TILFORD



## Earth Observing System

### Science & Mission Requirements Working Group Recommendations

1. A PROGRAM MUST BE INITIATED TO ENSURE THAT PRESENT TIME SERIES OF EARTH SCIENCE DATA ARE MAINTAINED AND CONTINUED. COLLECTION OF NEW DATA SETS SHOULD BE INITIATED.
2. A DATA SYSTEM THAT PROVIDES EASY, INTEGRATED, AND COMPLETE ACCESS TO PAST, PRESENT AND FUTURE DATA MUST BE DEVELOPED AS SOON AS POSSIBLE.
3. A LONG-TERM RESEARCH EFFORT MUST BE SUSTAINED TO STUDY AND UNDERSTAND THESE TIME SERIES OF EARTH OBSERVATIONS.
4. EOS, THE EARTH OBSERVING SYSTEM SHOULD BE ESTABLISHED AS AN INFORMATION SYSTEM TO CARRY OUT THOSE ASPECTS OF THE ABOVE RECOMMENDATIONS WHICH GO BEYOND EXISTING AND CURRENTLY PLANNED ACTIVITIES.
5. THE SCIENTIFIC DIRECTION OF THE EARTH OBSERVING SYSTEM SHOULD BE ESTABLISHED AND CONTINUED THROUGH AN INTERNATIONAL SCIENTIFIC STEERING COMMITTEE.

# EARTH OBSERVING SYSTEM

(Eos)

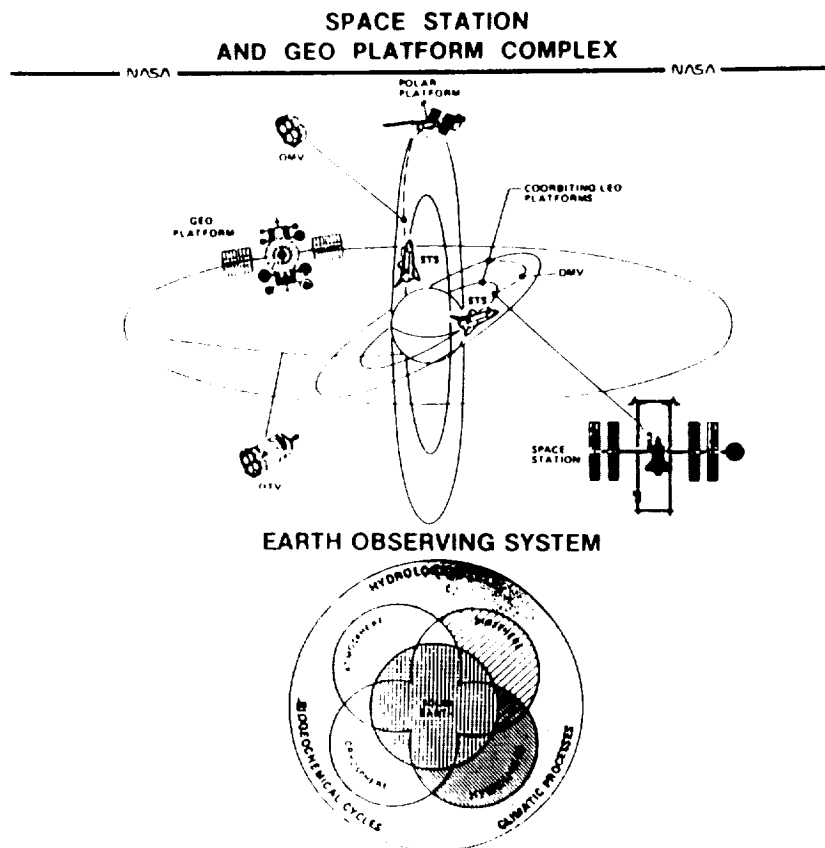
## CONCEPT

AN INFORMATION SYSTEM ESTABLISHED TO MEET THE MULTI-DISCIPLINARY NEEDS OF EARTH SCIENCE THAT GO BEYOND THE CURRENTLY PLANNED RESEARCH AND OPERATIONAL OBSERVING PROGRAMS.

INCLUDES:

DATA SYSTEM

OBSERVING SYSTEM





## SELECTION OF EOS / POLAR PLATFORMS PAYLOADS

- SPACE STATION PARTNERSHIP USER OPERATIONS PANEL HAS FINAL AUTHORITY
  - DELEGATION TO EARTH OBSERVATIONS OFFICES OF SPACE STATION PARTNERS ANTICIPATED
  - CURRENT PLANNING THROUGH THE COORDINATION WORKING GROUP
    - MANAGEMENT LEVEL REPRESENTATIVES OF NASA, ESA, JAPAN, CANADA, NOAA, EUMETSAT
    - DISCUSSING PAYLOAD PROVISION, AO PROCESS, PLATFORM REQUIREMENTS, ETC.
    - 3 MEETINGS HELD LAST YEAR, 2 HELD THIS YEAR, 2 MORE PLANNED PRIOR TO AO RELEASE
  - AO SELECTION PROCESS WILL INVOLVE THE SCIENCE COMMUNITY IN OSSA EOS PREPARATION
    - INSTRUMENT INVESTIGATIONS WILL PROVIDE WELL-DEFINED POTENTIAL PAYLOAD ELEMENTS
    - FACILITY INSTRUMENT TEAMS WILL PROVIDE METHOD TO PARTICIPATE IN LARGE INSTRUMENTS
  - COMMERCIAL INSTRUMENT ALLOCATION LEFT TO SPACE STATION PARTNERSHIP
- 

## EOS INSTRUMENTS SELECTION PROCESS BY INSTRUMENT TYPE

- RESEARCH FACILITY INSTRUMENTS
  - PROVIDED BY NASA, ESA, JAPAN, OR CANADA
  - DEVELOPMENT BY INSTITUTIONAL CENTER
  - RESEARCH TEAM ASSEMBLED FROM THE SCIENCE COMMUNITY
- OPERATIONAL FACILITY INSTRUMENTS
  - PRIMARILY EXTENSIONS OF NOAA K,L,M PAYLOAD
  - PROVIDED BY NOAA OR THROUGH NOAA AGREEMENTS
- AO/PI INSTRUMENT INVESTIGATIONS
  - RESEARCH INSTRUMENTS FROM PRINCIPAL INVESTIGATORS
  - PEER-REVIEWED PROPOSALS
  - U.S. PROPOSALS FOR NASA SUPPORT
  - NON-U.S. PROPOSALS ARE NATIONAL CONTRIBUTIONS

## **AO CONTENT**

- **NASA Will SOLICIT:**
    - PI/AO INSTRUMENTS
    - RESEARCH FACILITY INSTRUMENT TEAM MEMBERS / LEADERS
    - INTERDISCIPLINARY INVESTIGATIONS (DATA ANALYSIS &/OR THEORY)
  - **ESA Will SOLICIT:**
    - PI/AO INSTRUMENTS
    - PI PROPOSALS OF INSTRUMENTS FOR ESA DEVELOPMENT
  - **JAPAN Will SOLICIT:**
    - JAPANESE PI/AO INSTRUMENTS
    - INTERNATIONAL FACILITY INSTRUMENT TEAM MEMBERS
  - **AO's NOT RESTRICTED TO IOC CAPABILITY OR CANDIDATE LISTS**
- 

## **TYPES OF INVESTIGATIONS**

- **INSTRUMENT INVESTIGATIONS**
- **INTERDISCIPLINARY INVESTIGATIONS**
- **TEAM LEADER/TEAM MEMBER INVESTIGATIONS**

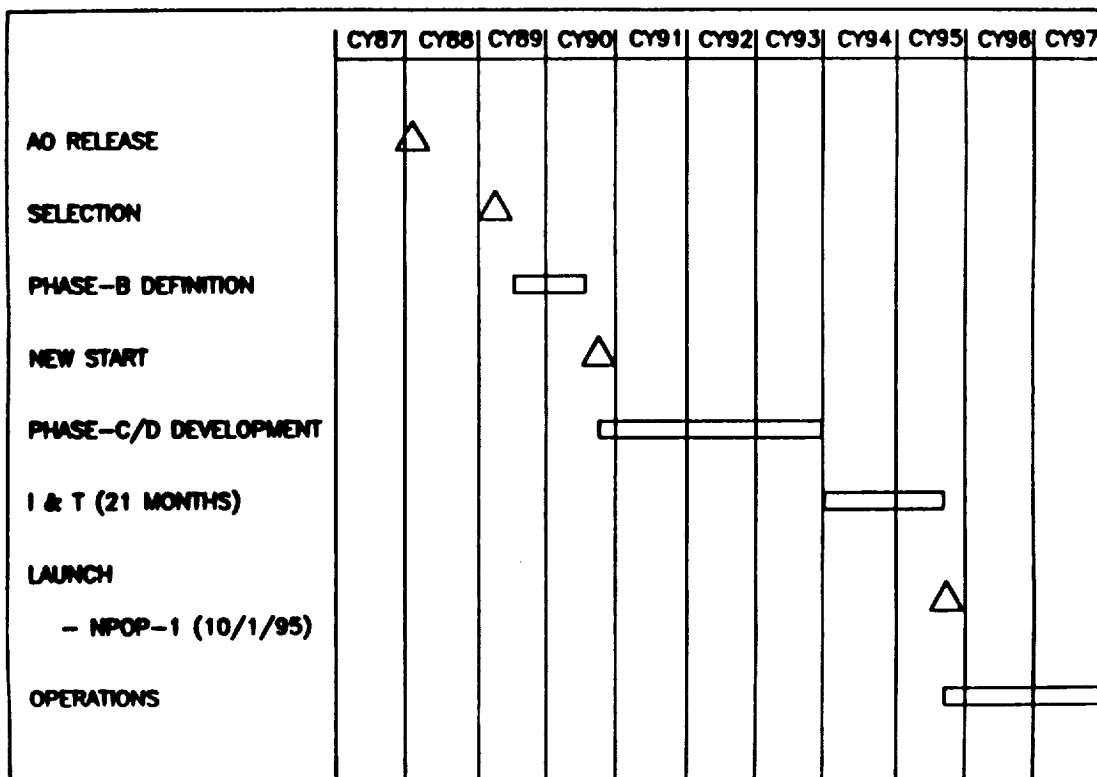
### **NASA DESIGNATED EOS FACILITY INSTRUMENTS**

- **MODIS**      **GSFC TO MANAGE BOTH NADIR AND TILT COMPONENTS**
  - **HIRIS**      **JPL TO MANAGE AS OUTGROWTH OF SISEX PROGRAM**
  - **SAR**      **JPL TO MANAGE AS OUTGROWTH OF SIR SERIES WITH X-BAND FROM FRG/ITALY**
  - **GLRS**      **GSFC TO MANAGE BASED ON LATE 70'S DEVELOPMENT PLAN**
  - **LAWS**      **MSFC TO MANAGE AND EXPLORE INTERNATIONAL COOPERATION**
  - **LASA**      **LaRC TO MANAGE LASER SUPPORT FACILITY AS OUTGROWTH OF LASE & LITE**
- 

### **CURRENT EOS PLANNING SCHEDULE**

- |                          |  |
|--------------------------|--|
| <b>OCTOBER 1, 1987</b>   | <b>START PHASE B STUDIES OF HIRIS, MODIS, AND GLRS FACILITY INSTRUMENTS</b>      |
| <b>JANUARY 15, 1988</b>  | <b>ISSUE EOS ANNOUNCEMENT OF OPPORTUNITY</b>                                     |
| <b>JULY 15, 1988</b>     | <b>LATEST DUE DATE FOR PROPOSALS</b>   |
| <b>OCTOBER 1, 1988</b>   | <b>PROCEED WITH HIRIS DEVELOPMENT &amp; EXTENDED PHASE B STUDY OF MODIS , GL</b> |
| <b>FEBRUARY 15, 1989</b> | <b>ANNOUNCE PRELIMINARY SELECTION FOR PHASE B STUDIES OF CANDIDATE PI INSTR</b>  |
| <b>OCTOBER 1, 1990</b>   | <b>BEGIN EOS PHASE C/D IMPLEMENTATION</b>  |
| <b>JANUARY 1, 1994</b>   | <b>DELIVER AO &amp; PI INSTRUMENTS FOR FIRST NASA AND ESA PLATFORMS</b>          |
| <b>JULY 1, 1995</b>      | <b>COMPLETE PLATFORM AND PAYLOAD INTEGRATION</b>                                 |
| <b>OCTOBER 1, 1995</b>   | <b>LAUNCH FIRST POLAR PLATFORM</b>   |

# INSTRUMENT PROGRAM SCHEDULE OVERVIEW



## GEOBASED INFORMATION SYSTEM

### EXAMPLES OF DATA BASE PARAMETERS

ATMOSPHERIC PARAMETERS

EVAPOTRANSPIRATION

TOPOGRAPHY

CULTURAL SITES

VEGETATIVE COVER/BIOMASS

SOIL MOISTURE

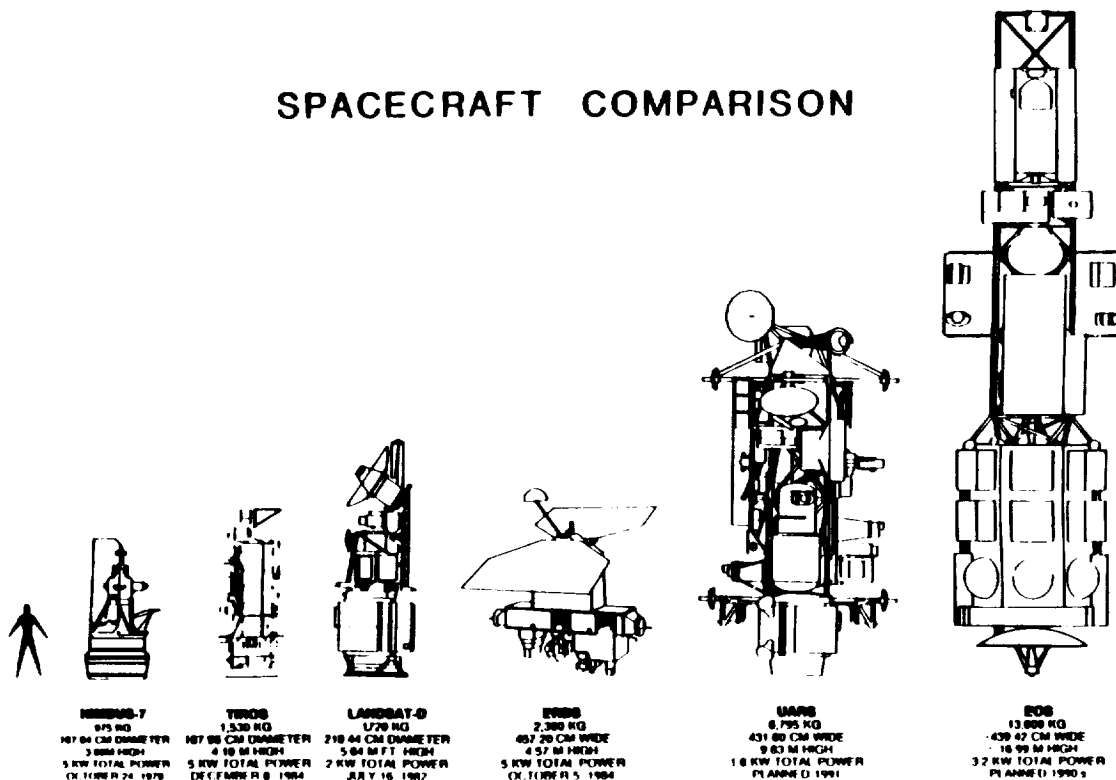
GEOLOGIC STRUCTURES AND SOILS DATA

NASA AMES RESEARCH INSTITUTE  
11/17/94

## ON-ORBIT SERVICING OF POLAR PLATFORMS

- NASA BASELINE IS "QUASI-ROBOTIC" SERVICING -- RMS AT SHUTTLE WITH EVA BACKUP
- ESA & JAPAN CURRENTLY LOOKING TO NASA FOR SERVICING
- ALTERNATIVE UNDER CONSIDERATION GIVEN WTR SHUTTLE CAPABILITY: SERVICEABILITY
  - RETAIN MODULAR APPROACH TO PLATFORM & PAYLOAD WITH SIMPLE MAKE/BREAK INTERFACES
  - EXAMINE COSTS FOR RETAINING OTHER SERVICING CAPABILITIES
  - BASELINE 3 YEAR SERVICING INTERVAL WITH 5 YEAR LIFETIME AS A CONTINGENCY
- SERVICEABILITY SUPPORTS:
  - PLATFORM OR ELV BASED ROBOTIC SERVICING: ELV RESUPPLY FOR OMV SERVICING
  - LONG-LIVED EXPENDABLE APPROACH FOR FIRST SET OF POLAR PLATFORMS
  - SPACE STATION SERVICING OF FUTURE LOW INCLINATION PLATFORMS UNDER GENERIC DESIGN

## SPACECRAFT COMPARISON



# E08 BASELINE PLANNING SCENARIO \*

PLATFORM ALT/CROSSING	NPOP -1 824 KM/1:30 PM	EPOP -1 824 KM/9:30 AM	NPOP - 2 824 KM/1:30 PM	JPOP -1 800KM/10-12:00 NOON
RESEARCH	MERIS (MODIS-T) MODIS-N  ITIR AMSR SCATT-1 ALT-1 CR MAG MPD	HRIS ATLID GLRS SCATT-2 ALT-2 SAR-C ATSR + CSR (ERBI (S)) MAG MPD AMR	IR-RAD SUB-MM F/P-INT MAG MPD SUSIM MLS	OCTS AVNIR LAVI AMSR (SAR-L) SAR-X
OPERATIONAL	AMRIR (2) GOMR ERBI (NS) ERBI (S) (CSR) AMSU (2) SEM	AMRIR (2) ERBI (NS) AMSU (2) SEM		
OTHER	ARGOS + S & R DB PPS/PODS P/L-EXEC	ARGOS + S & R PPS-PODS DB #	DB P/L-EXEC	<input type="checkbox"/> NASA/NO <input type="checkbox"/> NOAA <input type="checkbox"/> GSFC FACILITY <input type="checkbox"/> INTERNATIONAL

\* REVISION 2 FROM INTERNATIONAL COORDINATION WORKING GROUP MEETING OTTAWA, MAY 1987  
# MERIS IN S/C BUDGET  
(X) REDUNDANT INSTRUMENTS  
(ACRONYM) PROPOSED PAYLOAD  
NASA NPOP-1,2 ESA EPOP-1, JAPAN JPOP-1

U.S. M.F. FACILITY

## REQUIREMENTS - PLATFORM 1 - NPOP-1

INSTRUMENT	MASS (KG)	POWER (W)		DATA RATE (MBPS)	
		AVG.	PEAK	AVG.	PEAK
MERIS	75	100	100	2.4	4.5
MODIS-N	200	500	500	3.5	8.4
HRIS	1080	620	825	3.5	290
ITIR	290	650	650	10*	52
AMSR	320	300	300	<.1	<.1
SCATT-1	180	240	240	.005	.005
ALT-1	180	225	225	.008	.013
CR	100	100	100	.001	.001
MAG	10	10	10	.002	.002
MPD	10	10	10	.001	.001
AMRIR (2)	125	50	50	4.0	4.0
GOMR	150	260	260	.003	.005
ERBI (NS)	35	20	20	.001	.001
ERBI (S)	30	30	30	.001	.001
AMSU (2)	210	200	200	.005	.005
SEM	20	20	20	<.001	<.001
ARGOS+	70	50	50	.002	.002
S & R	50	70	70	.005	.005
DB	110	140	140	N/A	N/A
PPS-PODS	40	30	30	<.001	<.001
TOTALS	3285KG	3625W	3830W	23MBPS	300MBPS#

\* ASSUMES ~20% D.C.  
# DATA RATE LIMIT OF 2 TORSS LINKS

M.J.D. 6/24/87

## REQUIREMENTS - PLATFORM 2 - NPOP-2

INSTRUMENT	MASS (KG)	POWER (W)		DATA RATE (MBPS)	
		AVG.	PEAK	AVG.	PEAK
SAR	1940	2300	11800	35	300
IR-RAD (CLRS)	150	430	430	.004	.004
SUB-MM (FIRE)	500	100	100	.003	.003
F/P-INT	115	100	100	.005	.005
MAG	10	10	10	.002	.002
MPD	10	10	10	.001	.001
PEM	80	75	75	.004	.004
SUSIM	110	20	20	.002	.002
MLS	400	500	500	.01	.01
DB	110	50	50	—	—
TOTALS	3425KG	3595W	13095W	35MBPS	300MBPS

M.J.D. 6/24/87

## REQUIREMENTS - PLATFORM 3 - EPOP-1

INSTRUMENT	MASS (KG)	POWER (W)		DATA RATE (MBPS)	
		AVG.	PEAK	AVG.	PEAK
HRIS	400	350	350	39.2	200
ATLID	150	800	800	1.0	1.0
GLRS	340	240	800	.01	0.1
SAR-C	600	1450	1735	150	200
ATSR+	80	80	80	.114	.215
SCATT-2	180	175	240	.003	.005
ALT-2	180	300	300	.013	.013
CSR	60	100	100	.008	.008
MAG	10	10	10	.002	.002
MPD	10	10	10	.001	.001
AMIR	230	300	300	0.1	0.1
AMRIR (2)	125	50	50	4.0	4.0
ERBI (NS)	35	20	20	.001	.001
AMSU (2)	210	200	200	.005	.005
SEM	20	20	20	<.001	<.001
ARGOS+	70	50	50	.002	.002
S & R	50	70	70	.005	.005
PPS-PODS	40	30	30	<.001	<.001
TOTALS	2860KG	4295W	5205W	194MBPS	405MBPS

M.J.D. 6/24/87

# 

INSTRUMENT	MASS (KG)	POWER (W)		DATA RATE (MBPS)	
		AVG.	PEAK	AVG.	PEAK
OCTS	180	120	240	1.5	4.5
(MODIS-N)	(200)	(500)	(500)	(3.5)	(8.4)
VNR/SWIR	200	200	340	15	60
LAWS	800	800	3000	0.3	1.0
AMSR	320	300	300	< 0.1	< 0.1
(SAR-L)	(450)	---	(1500)	---	---
SAR-X	600	1200	6000	40	200
TOTALS*	2100KG	2620W	9880W	57MBPS	266MBPS

\* () INSTRUMENTS NON-ADDITIVE

M.J.D. 6/24/87

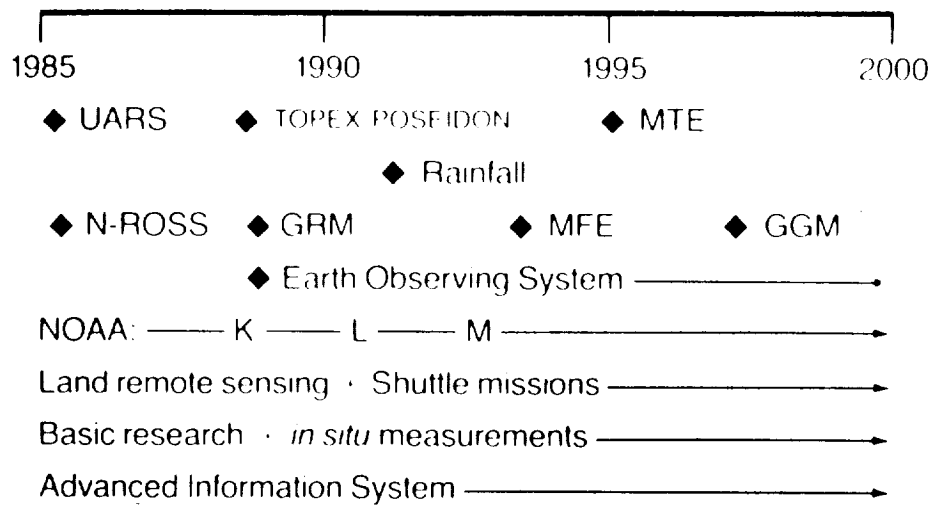
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JULY 1987

ALT	RADAR ALTIMETER (1-NASA, 2-ESA)	LAWS	LASER ATMOSPHERIC WIND SOUNDER
AMIR	ADVANCED MICROWAVE IMAGING RADAR	MAG	MAGNETOSPHERE CURRENTS/FIELDS
AMRIR	ADVANCED MEDIUM RESOLUTION INFRARED RADIOMETER	MERIS	MEDIUM RESOLUTION IMAGING SPECTROMETER
AMSR	ADVANCED MICROWAVE SCANNING RADIOMETER	MLS	MICROWAVE LIMB SOUNDER
AMSU	ADVANCED MICROWAVE SOUNDING UNIT	MODIS-N	MODERATE RESOLUTION IMAGING SPECTROMETER-NADIR
ARGOS +	DATA COLLECTION SYSTEM (FRENCH)	MODIS-T	MODERATE RESOLUTION IMAGING SPECTROMETER-TILT
ATLID	ATMOSPHERIC LIDAR	MPD	MAGNETOSPHERE CURRENTS/FIELDS
ATSR +	ALONG TRACK SCANNING RADIOMETER	OCTS	OCEAN COLOR & TEMP. SCANNER
AVNIR	ADVANCED VERY HIGH RESOLUTION RADIOMETER	P/L-EXEC	PAYLOAD EXECUTIVE
CR	CORRELATION RADIOMETER	PEM	PARTICLE ENVIRONMENT MONITOR
CSR	CONICALLY SCANNING RADIOMETER	PPS-PODS	PRECISE POSITION SYSTEM-PRECISE ORBIT DETERMINATION SYSTEM
DB	DIRECT BROADCAST	S & R	SEARCH AND RESCUE
ERBI	EARTH RADIATION BUDGET INSTRUMENT (NS-NON-SCANNER) (S-SCANNER)	SAR	SYNTHETIC APERTURE RADAR (C, L, & X BANDS)
F/P-INT	FABRY PEROT INTERFEROMETER	SCATT	SCATTEROMETER (1-NASA, 2-ESA)
GLRS	GEODYNAMICS LASER RANGING SYSTEM	SEM	SPACE ENVIRONMENT MONITOR
GOMR	GLOBAL OZONE MONITORING RADIOMETER	SUB-MM	SUBMILLIMETER SPECTROMETER
HIRIS	HIGH RESOLUTION IMAGING SPECTROMETER	SUSIM	SOLAR UV SPECTRAL IRRADIANCE MONITOR
IR-RAD	IR RADIOMETER		
ITIR	INTERMEDIATE THERMAL INFRARED RADIOMETER		



# EARTH SYSTEM SCIENCE THROUGH YEAR 2000



Earth System Science

## LAUNCH OF POLAR PLATFORMS

- NASA OPTION FOR TITAN-IV PLATFORM LAUNCH MEETS EOS USER REQUIREMENTS
- ESA PLANS ARIANE V FOR COMPARABLE PLATFORM PAYLOAD CAPACITY
- NASDA PLANS H2 FOR A HALF-SIZE PLATFORM (1997-98)

## **Eos MAJOR EARTH SCIENCE GOALS**

### **HYDROLOGIC CYCLE**

- QUANTIFY THE PROCESSES OF PRECIPITATION, EVAPORATION, EVAPOTRANSPIRATION, AND RUNOFF ON A GLOBAL BASIS
- DETERMINE WHAT FACTORS CONTROL THE HYDROLOGIC CYCLE
- QUANTIFY THE INTERACTIONS BETWEEN THE VEGETATION, SOIL, AND TOPOGRAPHIC CHARACTERISTICS OF THE LAND SURFACE AND THE COMPONENTS OF THE HYDROLOGIC CYCLE

### **BIOGEOCHEMISTRY**

- UNDERSTAND THE BIOGEOCHEMICAL CYCLING OF CARBON, NITROGEN, PHOSPHOROUS, SULFUR AND TRACE METALS
- DETERMINE THE GLOBAL DISTRIBUTION OF BIOMASS AND WHAT CONTROLS BOTH ITS HETEROGENEOUS DISTRIBUTION IN SPACE AND ITS CHANGE OVER TIME
- QUANTIFY THE GLOBAL DISTRIBUTION AND TRANSPORT OF TROPOSPHERIC GASES AND AEROSOLS AND DETERMINE THE STRENGTHS OF THEIR SOURCES AND SINKS IN THE OCEAN, LAND SURFACE, COASTAL AND INLAND WATERS, AND UPPER ATMOSPHERE

### **CLIMATOLOGICAL PROCESSES**

- PREDICT CLIMATE ON A PROBABILISTIC BASIS
- DETERMINE THE RESPONSE OF THE ATMOSPHERE TO CHANGES IN THE OCEAN CIRCULATION AND HEAT CONTENT, LAND SURFACE, AND SOLAR INPUT
- DETERMINE THE ROLE OF SEA AND LAND ICE COVER IN CONTROLLING GLOBAL CLIMATE

FILE NAME 1-01

7

NASA HQ FF 12-6-84

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## **Eos MAJOR EARTH SCIENCE GOALS (Cont.) GEOPHYSICAL PROCESSES**

### **ATMOSPHERIC**

- UNDERSTAND THE COUPLING OF THE CHEMICAL, RADIATIVE, AND DYNAMIC PROCESSES OF THE TROPOSPHERE, STRATOSPHERE, AND MESOSPHERE
- DETERMINE THE COUPLING BETWEEN THE LOWER AND UPPER ATMOSPHERE
- EXTEND DETERMINISTIC WEATHER FORECASTING TOWARDS ITS THEORETICAL LIMIT

### **OCEANIC**

- MEASURE THE MESOSCALE TO LARGE SCALE CIRCULATION OF THE OCEAN AND ACQUIRE A BETTER UNDERSTANDING OF THE LONG TERM VARIABILITY IN THIS CIRCULATION
- DETERMINE THE GLOBAL HEAT, MASS, AND MOMENTUM COUPLING BETWEEN THE OCEAN AND ATMOSPHERE
- UNDERSTAND THE PROCESSES CONTROLLING THE DYNAMICS OF SEA ICE AND ITS INTERACTION WITH THE UNDERLYING WATER

### **SOLID EARTH**

- DETERMINE THE GLOBAL DISTRIBUTION, GEOMETRY, AND COMPOSITION OF CONTINENTAL ROCK UNITS
- UNDERSTAND HOW EPISODIC PROCESSES SUCH AS RAINFALL, RUNOFF, DUST STORMS, AND VOLCANISM MODIFY THE SURFACE OF THE EARTH
- DETERMINE THE RELATION BETWEEN THE FACTORS OF CLIMATE, TOPOGRAPHY, VEGETATION AND THE GEOLOGIC SUBSTRATE AND THE PROCESSES OF SOIL FORMATION AND DEGRADATION

FILE NAME 1-02

256

NASA HQ FF 12-6-84



## EARTH AND OCEAN OBSERVATION PANEL SUMMARY

### OPENING PLENARY SESSION

1. The Commercial Earth and Ocean Observation Panel plenary session began on 4 November with instructions to the sub-panel chairmen by the panel co-chairmen, Dr. Shelby Tilford and Dr. Charles Whitehurst. Mr. Robert Kelly, Lockheed/NSTL, reviewed the current status of Space Station Commercial Earth and Ocean Observation missions defined in the Mission Requirements Data Base (MRDB). A demonstration of on-line PC access to the MRDB was provided by Computer Sciences Corporation support personnel from Johnson Space Center.

2. The panel then divided into separate work groups for each of its four sub-panels. After initial deliberations, the Oceanic and Atmosphere sub-panel voted to dissolve and incorporate its members into the other three sub-panels due to inadequate representation of representative end-users. The other three sub-panels continued effective deliberations during the evening of 4 November.

### EARTH AND OCEAN OBSERVATION SUB-PANEL DISCUSSION SUMMARIES

#### ADVANCED APPLICATIONS SUB-PANEL SUMMARY

Advanced Applications Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
John Bossler	CCDS Director	Ohio State Univ
David A. Christensen	Supervisor R&D	Pacific Gas & Electric Co.
Holmes S. Moore	Consultant	Center for Space and Advanced Technology
Bob Cameron	Director	Applied Sciences Inc
Leon Goldshlak	Marketing Manager	Hughes/Santa Barbara
	Space Sensors	Research Center
Chet Borden	Group Supervisor	Jet Propulsion Lab
Andy Biache	Senior V.P.	Autometric, Inc.
Wayne Bailey	Systems Analyst	Teledyne Brown Engineering
John L. McIver	Account Manager	Boeing
Dominick A. Aievoli	Program Manager	G.E. Astro-Space
	Space Station	
	Work Package 3	
Jim Lawless	Br. Chief	Ames Research Center
	Ecosystems	Science & Technology Branch

Joan Salute	Research Scientist	TGS Technology
Warren Hovis	Chief Scientist	Ames Research Center
Charles Whitehurst	Director	TS, Infosystems, Inc.
E.A. Brown	Director, Commercial	Earth Resources Lab
	Uses of Space	Boeing
Carl Schueller	Director	ITD/SRSC - Mississippi
		CCDS

1. The Advanced Applications sub-panel discussed radar pointability as a partial solution to data frequency and stereo needs. This is a requirement on both the 28° and polar platforms and is an end-to-end problem. This is a partial solution to the news (media) and disaster issues. SPOT IMAGE has identified that there is a user market. The sub-panel recommends that NASA Code C task someone to understand and identify the market applications.
2. The sub-panel discussed the need to combine radar and visible imaging on the 28° inclination orbit. The Earth Observing System synthetic aperture Radar (EOS SAR) is too limited in area of coverage. The sub-panel identified the need for a research program driven by commercial needs which will generate data to be used in designing future less expensive commercial systems. This combination would allow greatly increased frequency of overpasses and make possible topographic mapping with stereo radar. The sub-panel agreed that radar is the key to the future as a commercial sensor for geology and other applications. The government should work with industry to identify a mechanism for implementation and encourage/allow development to continue.
3. The sub-panel discussed the cost/pricing and utilization charges that will be levied by NASA on the commercial users. Industry needs to know the projected costs and rationale for services such as transport of hardware, astronaut time, etc., in order to price their products. Such cost will be passed on to the customer. The long term pricing policies need to be provided to industry along with the resolution of the priority of resources issue. The sub-panel recommends that NASA Code S identify the pricing elements (costs and criteria for costs) for both the polar platform and 28° platform services.
4. The sub-panel discussed the potential of using a special purpose radar to probe the ground and polar ice. This would be a scaled-up space version of an earth penetrating commercial radar currently operational on an aircraft platform. There are a number of potential commercial applications of the radar including pipeline and underground storage tank leak detection. The sub-panel recommended that a developmental version of this radar be deployed on the 28° core Space Station or on a co-orbiting platform for test and integrated experimentation with other surface imagers. The radar would evolve for eventual deployment on the polar platform. This is a new mission which the sub-panel proposes for inclusion in the MRDB and an end-to-end capability needs to be laid out.
5. The sub-panel discussed the need for a mechanism to feed industry requirements into the NASA "system". This is not one "large" industry but an aggregate of small businesses to create a commercial consortium. NASA needs to understand how industry motivations and operations work. The sub-panel recommends that an earth and ocean observations sub-



operations work. The sub-panel recommends that an earth and ocean observations sub-group be formed within NASSAU, the National Association of Space Station Applications & Utilization. The sensor builders or value-added industry should be approached to "champion" this effort.

6. The sub-panel discussed the requirement for direct downlink to users from the platforms. The TDRSS (tracking and data relay satellite system) will not be capable of meeting commercial requirements. Customers will need real time delivery for specific commercial applications. Customers also want proprietary protection of competition sensitive data. The panel questioned whether the Land Remote Sensing Commercialization Act will prohibit response to this requirement. This request has been brought up at all three Remote Sensing commercial mission parameter workshops and the sub-panel asked what has been done about it. The sub-panel recommends direct down link for both the polar platform and the 28° platforms. This service may potentially be provided by an industrial service firm. NASA needs to provide regulations and technology to allow this to be accomplished and to develop policy to match this new thrust. The sub-panel proposes the direct downlink be included as a mission in the MRDB.

7. The sub-panel discussed the impacts of the Department of Defense implied limitations on the spatial resolution of satellite imaging data on U.S. corporations. The limitation, currently at 10 meters puts U.S. companies at a competitive disadvantage since other countries do not impose this limit. For example, the Soviets are selling data with 5 meter resolution. The sub-panel recognizes that with these international capabilities, the U.S. is at a competitive disadvantage. The sub-panel recommends that the U.S. policy be revisited and possibly revised to enable U.S. companies to compete internationally.

8. The sub-panel discussed the requirement for manned observations on the 28° inclination platforms. The sub-panel feels this is a requirement because:

- Data analysis may be required on orbit;
- Artificial Intelligence (AI) techniques are not ready to meet this requirement;
- There may be targets of opportunity to respond to for observation; and
- On demand observation of selected targets may be required.

The sub-panel noted that the Soviets have always made extensive use of Cosmonauts in-the-loop for remote sensing missions on the manned Space Station using aids such as binoculars and color atlases. They have reported significant improvements in visual performance after long periods in space. The specific reasons why the Soviets have used humans in the loop are not clear. One reason offered by the sub-panel was their lack of electro-optical capabilities but there may be other reasons. The sub-panel concluded that valuable insight can be gained from manned observation experiments for data filtering and for eventual application to AI techniques for smart sensors. The sub-panel recommends the current place holder mission (TDMX 2262) for manned observation techniques on the core Space Station be maintained and that an optical quality Nadir viewing window be provided. Additionally, the sub-panel supports MRDB mission COMM 1014 (Remote Sensing Test, Development, and Verification Facility) and urges NASA to make sure it has a pointing capability.



9. The sub-panel discussed the current polar platform servicing schedule and agreed that it is not acceptable. The current revisit schedule is 3 years. Commercial data suppliers will have to guarantee data availability to their customers. If the data continuity is lost, they will have to pay delinquency charges. The sub-panel does not feel that "spare parts" is the answer and that the answer lies in reducing the risk through redundant sensors. The sub-panel recommends that the user provide for redundancy and as insurance, save space on ESA platforms and have 2 copies of each sensor on each platform (i.e. 4 identical sensors). To accomplish this, NASA must assure opportunities for U.S. commercial industry to have access to non-U.S. platforms.

10. The sub-panel discussed the need for a priority policy for access to the polar platform and the 28° resources. NASA needs to develop rationale for allocation of TDRSS, power, and other platform resources. The policy needs to be developed for all scenarios (operational and experimental, planned and unplanned). When a resource is reduced industry needs to know what NASA's policy will be. This policy must also be linked to the pricing structures. The sub-panel feels that industry needs a voice in this process. The sub-panel recommends that some future workshops be conducted at the "business" level -- i.e. how to do business with the government.

11. The sub-panel discussed the future NASA geostationary platform which is planned to be an aspect of the Space Station infrastructure. This issue was addressed because a number of the advanced mission applications identified by the sub-panel require continuous 24 hour coverage. For example, monitoring and localization of lightning strikes on electrical power sites, real time monitoring of pollution plumes from environmental incidents, and real time ship routing were identified as commercial applications requiring a geostationary platform. Industry needs NASA commitment that there will be a geostationary platform or platforms as part of the Space Station infrastructure to ensure commercial development of sensors. Sensor development for the geo platforms could proceed on aircraft and on the 28° core station. "The Mission to Planet Earth" identified in the Ride report could be reinforced by the early introduction of commercial requirements for the geo platform. This is perfect time to foster government/industry cooperation. Industry interest which has been exhibited could stimulate the geo platform effort. The sub-panel recommends that NASA include industry on the planning committees for this platform.

12. The sub-panel discussed the possibility of Government and Industry sharing instruments and data. This would be accomplished by opening up EOS payloads. Industry would take data collected by sensors on the platform and perform testing to determine what new information is available and the potential for new markets for that data. Industry/Government could co-fund instruments in an effort to develop the utility of the data. This would reduce private industries risk in determining new sensor utility and new products. The government, industry, and academia would have ready access to new sensors on a cost-sharing basis. The sub-panel recommends that the issues of proprietary rights and the co-funding opportunities be addressed. The sub-panel feels that this is another example of new ways for government to do business with industry and that it should be explored and not allowed to drop for another two years.



13. The sub-panel discussed the need for analog data and determined that analog data should be provided from both the 28° and polar platforms. The sub-panel feels that this would be matching the technology to the requirements - they are both simple - and it could be done cheaply. Users would have access to cheap products. This would include both film from the 28° platform and analog electronic data from the 28° and polar platforms. The sub-panel feels that there is definitely a market for low-cost, moderate quality imagery data (e.g., the fishing industry would use grey scale to identify upwelling) other potential users would also include the media. The sub-panel recommends that the 28° platform be used for test and proof-of-concept and that the individual in the loop should also be used to return "video" for selected studies. This should be very inexpensive to facilitate. The sub-panel recommends:

- NASA provide the opportunity, i.e., acknowledge the need;
- Space qualify existing hardware; and
- Develop a commercial end-to-end system.

## RENEWABLE RESOURCES SUB-PANEL SUMMARY

### Renewable Resources Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Robert Kelly	Program Manager	Lockheed
Buzz Sellman	Resource Manager	ERIM
Stan Morain	Director TAC	University of New Mexico/NASA
Jim Malanaphy	Assistant to the President	Farmland Industries, Inc.
Bernard Sanders	Vice President - Planning	Farmland Industries, Inc.
Richard Mroczynski	Director, Public Affairs	EOSAT
John Estes	Professor	Univ. of California Santa Barbara, CA
Lisa Mann	Applications Project Manager	Sterling Software Ames Research Center
Jim Yoder	Program Manager	NASA - Headquarters
W.L. Barnes	Branch Head	NASA/GSFC
Carl Schueler	Director	ITD SRSC
Warren Hovis	Chief Scientist	TSI, Inc.

1. The sub-panel discussed general areas of commercial applications in renewable resources. Prior to evaluating the commercial missions in the MRDB, the sub-panel identified application areas most valuable for commercial requirements. Topics discussed were agricultural applications, forestry, fisheries, land mapping and environmental management. For example, some of the most important characteristics to be determined



are health and vigor of crops, soil moisture, crop yield, biomass, etc. This discussion served as the basis and focal point for further evaluation of the COMM missions of the MRDB and for the issues revolving around sensors and applications in renewable resources. Sub-panel members were encouraged to keep in mind the focus of commercial applications revolving around renewable resources.

2. The sub-panel discussed several issues pertaining to commercial operations. These include data rates and priorities of data rates from the core platform and polar platform, the provision for direct data downlink, the need for repair priorities and schedules, the need for repeat coverage and timely data, platform stability and the need for more information on commercial opportunities for the polar platform. These issues are viewed as being key requirements for commercial users. The sub-panel recommended that NASA incorporate these issues into specifications of the mission parameters.

3. The sub-panel exclusively evaluated the MRDB missions with the prefix COMM (commercial missions). COMM 1014, Remote sensing test and validity; COMM 1015, large format camera; COMM 1019, EOSAT mission; COMM 1020 commercial SAR; and COMM 1023 Ocean color imager, were each addressed separately with the question of whether or not commercial renewable resource applications depended on these missions. The sub-panel concluded that the commercial SAR (COMM 1020) and the on-board remote sensing test and validation (COMM 1014) had no direct commercial renewable resource application associated with them. However, the other three COMM missions all have significant commercial applications. The sub-panel could not envision COMM 1014 and COMM 1020 useful as viewed from renewable resources perspective, although the COMM 1014 was supported for sensor testing and evaluation. The TDMX, SAAX, and NOAA missions were not reviewed for commercial applications or sub-panel recommendations.

- COMM 1015, Large Format Camera (LFC). The sub-panel discussed the LFC commercial applications in light of the low inclination orbit on the 28° platform. Commercial forestry, mapping, land-use planning and analysis were discussed as relevant applications. The LFC limitations were also discussed and include non-global data acquisition and odd spatial resolution. In addition, increased capability through a pointable attachment configuration is desired. The sub-panel concluded that the LFC is limited to those applications listed above due to its low inclination, although the variable earth illumination may have unusual advantages. The sub-panel recommends that NASA revise the MRDB for this mission time frame and to correct the spatial resolution from 14 x 25m to 10 x 10m. Finally, the sub-panel recommended that NASA modify the MRDB to include an attachment for a pointable mount.
- COMM 1019, EOSAT Mission. All renewable resources commercial applications (agriculture, forestry, fisheries, environmental management) are addressed by this mission. Sensor configuration of Thematic Mapper type instrument continues to be of high value to commercial users. The sub-panel concludes that the EOSAT mission is of high value to potential commercial applications.





- COMM 1023, Ocean Color Imager. The sub-panel identified commercial applications of the ocean color imager (OCI). The key applications identified include fisheries and ship routing. However, the use of the OCI can only be justified for use in coastal areas, assuming an EOS MODIS System which would operationally cover the deeper ocean areas. The sub-panel feels that there are viable commercial applications for the OCI, although, the spatial resolution of OCI needs to be increased in areas where MODIS is lacking. The sub-panel recommends the OCI spatial resolution be increased in the region where MODIS is lacking from 500 m to 200-300 m to perform all imaging activities.

### NON-RENEWABLE RESOURCES SUB-PANEL SUMMARY

#### Non-Renewable Resources Sub-Panel Participants

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Tony Barringer	CEO	Barringer Resources
Alfredo E. Prelat	Sr. Research Scientist	UNOCAL Science & Technology
Gerry Meeks	Chief Engineer	NASA/NSTL
Floyd Sabins	Sr. Research Associate	Chevron Oil Field Research Co.
Bob Vincent	President	GeoSpectra Corp.
Miriam Baltuck	Earth Resources Scientist	NASA/EEL
Fred Henderson	President	GEOSAT
Al Watkins	Director	Eros Data Center
Shelby Tilford	Division Director	NASA Headquarters

1. The non-renewable resources sub-panel discussed near-term commercial opportunities, research opportunities and needs, and commented on specific MRDB commercial missions in the remote sensing area.
2. The sub-panel identified near-term commercial opportunities for the large format camera (LFC) and radar.
  - The LFC is planned for installation on the core station. Since this location would limit camera coverage the commercial value of the LFC is questionable in the 28° inclination orbit particularly if global coverage is not possible.
  - The sub-panel endorses a Synthetic Aperture Radar (SAR) with L-Band, 25° depression angle of inclination, 100 km swath width on the polar orbit. The radar would require the pointing capability.



3. The sub-panel identified the following ten areas of research opportunities and needs in the non-renewable resources remote sensing area:

- Experimental radar with multi-frequency, multi-polarization variable depression angles
- Experimental precision laser altimetry with high resolutions registered optical imagery (GLARS)
- Multispectral thermal IR
- Narrow-band imaging spectrometer with tunable bands and bandwidth (5nm)
- Passive fluorescence detection research
- Detection of hydrocarbon seeps and spills (offshore and on land)
- Parametric evaluation of solar illumination angle and plane of incidence
- Capability for ice monitoring to support non-renewable resource development
- Precision topographic mapping capability
- Gravity satellite

4. The sub-panel discussed and commented on the following MRDB missions:

- COMM 1014, Remote sensing test, development, verification facility on-board core station
  - Parameters look reasonable -- supported by panel
- COMM 1015, Large format camera
  - Parameters reasonable
  - Low priority because of orbital limitations and film media
- TDMX 2261, Technology development facility for components of future sensors
  - No comment
- TDMX 2262, Develop manned observational techniques
  - Use to support basic research and technology development
- TDMX 2264, Passive microwave sensor development
  - Lower priority
  - Useful for study of ocean currents
- SAAX 220, Data collection/location platform
  - Need on polar platform, and core station
- SAAX 251, Tropical rainfall mapping
  - Weather for operations planning
  - Also, climate and global
- COMM 1019, Comm electro-optical imagers
  - MRDB high priority timing needs revision



- COMM 1020, COMM SAR
  - High priority for both operations and research
- COMM 1023, COMM ocean color imager
  - Supports high priority areas of research in detecting hydrocarbon seeps, current monitoring and silica deposition
- SAAX 202, EOS on polar platform
  - Very high priority  
(see issues re: budgetary reality, single mission, concept, commercial competition)

### **CLOSING PLENARY**

Upon completion of sub-panel activities on the morning of 5 November, the two co-chairmen met with the three sub-panel leaders to discuss the panel's findings and recommendations. They then developed summarizing presentation materials for Dr. Tilford's wrap-up presentation which was given to the Workshop plenary session later in the morning. During the sub-panel leader debriefings to the chairmen, the remaining sub-panel members met to discuss specific follow-on activities relative to the panel's findings and recommendations.





## INDUSTRIAL SERVICES PANEL

- Dr. Earle K. Huckins III, Director, Strategic Plans and Programs Division, Office of Space Station, provided the Workshop with an overview of the Industrial Services panel and the service aspects of the Space Station. Dr. Huckins discussed the Space Station's evolution concept and how commercial participation could result from this evolution -- especially through non-NASA sponsored evolution. Dr. Huckins also discussed the Space Station commercial infrastructure development program whose goal is to provide opportunities for U.S. commercial participation in the Space Station program.
- Mr. John J. Egan, President, The Egan Group, discussed commercial ownership and operation of Space Station systems and services and the concept of commercial participation. Mr. Egan's remarks discussed:
  - The concept of commercial services;
  - The benefits to NASA;
  - The benefits to industry;
  - Some basic issues, specific business issues, and some general business issues associated with the concept.





National Aeronautics and  
Space Administration

## INDUSTRIAL SERVICES OVERVIEW

DR. EARLE HUCKINS  
Strategic Plans and  
Programs Division  
Office of Space Station

NOVEMBER 4, 1987

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### PURPOSE OF INDUSTRIAL SERVICES PANEL

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- Address the services aspects of Space Station and its associated platforms
- Identify specific service requirements for users
  - On-orbit services
  - Transportation services
  - Ground services
- Address the issues of how commercial business can participate
- Address opportunities presented by Space Station Evolution

OSS-8207  
10/28/87

## EVOLUTION SCOPE AND POLICY

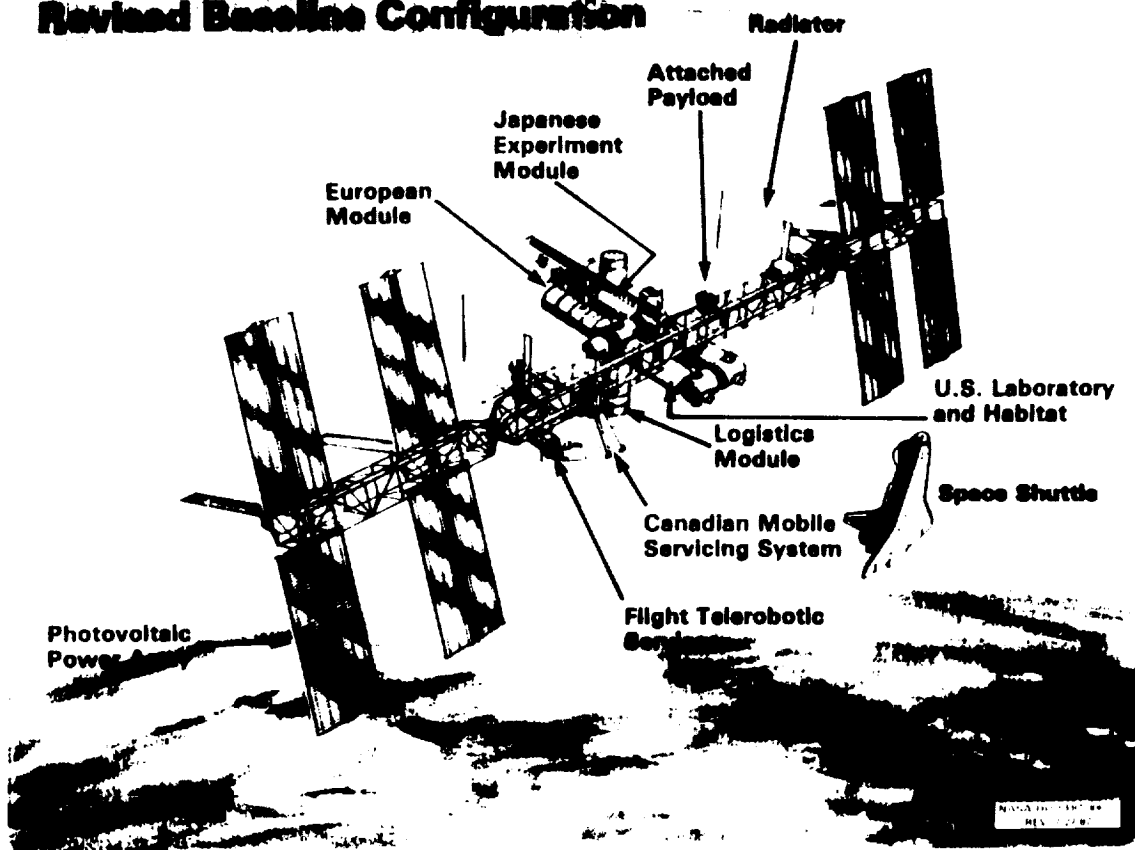
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- The initial Space Station will be designed to facilitate evolution
- Evolution includes all forms of increases in Space Station and Platforms capacities and capabilities to accommodate users
- Evolution will be in response to user needs and national or international initiatives
- Evolution may be sponsored by NASA, other federal agencies, other nations, or U.S. industry
- Evolution planning will include the participation of all NASA Centers and the Space Station Program Office
- NASA Space Station evolution planning will be coordinated and integrated with the planning of international partners

OSS-7594  
9/14/87

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### Revised Baseline Configuration





## DEFINITIONS

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- **Evolution:** Process of increasing the capability of the Space Station to meet users' requirements or needs. The evolution phase of the Space Station Program begins at the time of the "Assembly Complete" milestone of the initial Space Station
- **Technology Upgrade:** Addition or substitution of new technology for existing Space Station systems or subsystems
- **Growth:** A specific form of evolution deriving solely from a quantitative increase in the Space Station infrastructure
- **Branching:** A specific form of growth that leads to more than one Station or to additional platforms. A process where one or more user functions are moved off the initial Station to a replicated Space Station element

OSS-7600  
9/14/87

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## NON-NASA SPACE STATION EVOLUTION

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- Evolution will be in response to user needs and National or International initiatives
- Non-NASA Space Station evolution refers to all forms of increases in Space Station and Platform capacities and capabilities not sponsored by NASA to accommodate user needs
- Such evolution will be associated with the Space Station Program
- Three general categories of Non-NASA evolution
  - International
  - Other federal agencies
  - Commercial

OSS-5426  
05/12/87

## **COMMERCIAL SPACE STATION EVOLUTION**

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- **Space Station evolution privately sponsored by U.S. industry**
  - **Administration, Agency and Program policies encourage commercial utilization, development and operations of Space Station system and services**
  - **New relationship between NASA and industry required**
  - **Program policies and procedures to foster commercial participation to be developed**

OSS-5429  
9/14/87

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## **COMMERCIAL SPACE STATION EVOLUTION**

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### **FUNDAMENTALS**

- **Space Station evolution policies develop the climate conducive to industry investment in space infrastructure**
- **Space Station evolution planning incorporates recognition of potential industrial participation in providing space infrastructure**
- **Prerequisite for commercial involvement is the emergence of a viable customer base**

OSS-7595  
9/14/87

# COMMERCIAL SPACE STATION EVOLUTION

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## CONCEPT

- Growth allows expansion of space infrastructure by industry
  - Assumes successful use of Space Station to be catalyst
- Government may not need to provide additional infrastructure
  - Current NASA investment will establish necessary technology, production and operation foundations
- Industry could (should?) provide additional space infrastructure
  - Building upon current Space Station investment

OSS-7596  
9/15/87

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## NASA GUIDELINES FOR UNITED STATES COMMERCIAL ENTERPRISES FOR SPACE STATION DEVELOPMENT AND OPERATIONS

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- (1) NASA welcomes and encourages participation in Space Station development and operations by U. S. commercial enterprises which seek to develop with private funds Space Station systems and services.
- (2) NASA will entertain proposals for commercial development and operation of Space Station systems and services with the goal of achieving negotiated agreements between NASA and the enterprise.
- (3) Agreements shall be for specific services with responsibilities and interfaces clearly defined and shall be focused on achievement of objectives in specific time periods.
- (4) NASA will provide, where appropriate, incentives to the enterprise.
- (5) NASA safety standards will be applied where appropriate; standards such as reliability and quality assurance will be applied based on criticality to Space Station functions.

OSS11 38 C  
(1 of 2)  
Rev 11/26/86

**NASA GUIDELINES FOR UNITED STATES COMMERCIAL ENTERPRISES  
FOR SPACE STATION DEVELOPMENT AND OPERATIONS  
(Continued)**

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- (6) NASA will protect proprietary rights, and will ask for privately-owned data only when necessary to carry out its responsibilities.
- (7) U.S. commercial enterprises may, where appropriate, enter into agreements with NASA to receive technical assistance, including access to NASA data and facilities.
- (8) U.S. commercial enterprises will retain responsibility for sustaining engineering, operational support, financing and spare parts for their services.
- (9) U.S. commercial enterprises may offer their services to Space Station participants.

THESE GUIDELINES ARE DERIVED FROM NASA'S COMMERCIAL SPACE POLICY WHICH IMPLEMENTS THE COMMERCIAL INTENT OF PRESIDENT REAGAN'S NATIONAL SPACE POLICY. THEY ARE INTENDED TO PROVIDE A FRAMEWORK TO ENCOURAGE U. S. COMMERCIAL ENTERPRISE INVESTMENT AND INVOLVEMENT IN THE DEVELOPMENT AND OPERATION OF THE SPACE STATION.

OSSTT 38 C  
(2 of 2)  
Rev. 11/26/86

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## **PHASE C/D REQUEST FOR PROPOSALS**

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- Space Station Phase C/D Request for Proposals includes commercial development language
- RFP language requires bidders to propose two plans to assist NASA in promoting commercial opportunities:
  - plan to integrate a commercial element into the overall Program
  - plan to stimulate U.S. private investment and involvement in the Program
- Similar language in Flight Telerobotic System Phase B RFP

Space Station development could provide technology base that could be adapted to providing commercial services in space

OSSTT 5769  
10/26/87

## **SPACE STATION COMMERCIAL INFRASTRUCTURE DEVELOPMENT PROGRAM**

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- **Goal: To provide opportunities for U.S. commercial participation in the Space Station Program**
  - **Policy established August 1986**
  - **Phase C/D RFP's solicit contractors' ideas on how to establish commercial opportunities**
- **Process to encourage commercial opportunities is being developed**
  - **Recommend policies to be implemented**
  - **Develop prototype agreements between government and industry**
  - **Identify necessary interfaces and relationships between government, contractors, and companies**
  - **Establish process to effectively transfer advanced technology to U.S. industry**

OSS-2038  
6/12/87

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## **SPACE STATION COMMERCIAL PARTICIPATION**

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- **Commercial Utilization (Richard Halpern)**
  - **Microgravity Sciences**
  - **Remote Sensing**
- **Commercial Infrastructure (Earle Huckins)**
  - **Space Station Evolution**
  - **Industrial Services**

**Space Station is a facility to assist the potential  
commercial development of space**

OSS-7970  
10/27/87

# **COMMERCIAL OWNERSHIP AND OPERATION OF SPACE STATION SYSTEMS AND SERVICES**

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## **UNDERSTANDING THE CONCEPT OF COMMERCIAL PARTICIPATION**

**JOHN J. EGAN  
President  
The Egan Group**

**NOVEMBER 4, 1987**

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### **THE CONCEPT**

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- **Commercial business owns and operates a specific non-essential Space Station system or service as a commercial business**
- **It retains ownership and control of the assets**
- **It provides services to the users of the Space Station (NASA, International Partners, other government agencies, commercial business)**
- **Some examples of potential commercial services are:**
  - **Payload processing prior to launch**
  - **Telescience services**
  - **Supplementary power**

## **COMMERCIAL DEVELOPMENT AS PART OF THE PHASE C/D RFP**

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- **Wording in the Space Station design and construction Request For Proposal requires contractor development**
- **Specific wording is:**
  - **The contractor shall develop innovative initiatives to stimulate, from multiple sources, U.S. private sector investment and involvement in Space Station development and operations**
  - **The contractor will provide a commercial support plan, describing a clear generic approach for accommodating potential commercial involvement (initiated by either the contractor or the government) in providing Space Station systems and services**

OSS-7994  
10/30/87

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## **WHAT'S IN IT FOR NASA**

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- **Increased capability for Space Station without spending added government funds**
- **Trading capital equipment (construction) dollars for longer term operating dollars**
- **Expansion of support base for Space Station and program in general outside traditional NASA support group**
- **Perceived support of Reagan administration's general preference for commercial involvement**

OSS-7995  
10/27/87

## WHAT'S IN IT FOR INDUSTRY

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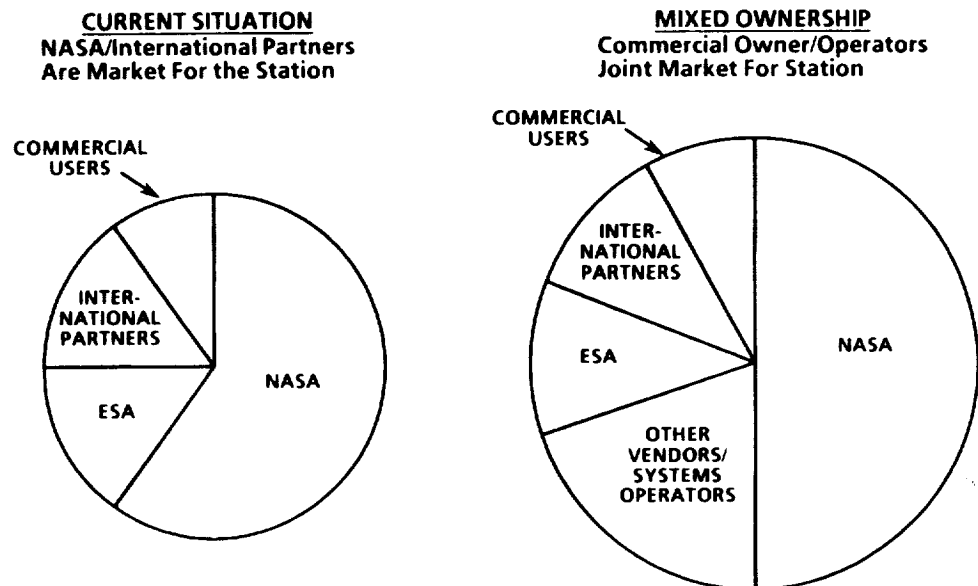
- Potential long term profit opportunity if proper deal can be struck
- Entree into a new market area at its birth
- Exposure to new technologies with potential spin-off into current business areas
- Public relations exposure as forward looking, high technology/advanced/progressive company

OSS 7996  
10/27/87

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## MARKET FOR SPACE STATION SERVICES

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VENDORS BECOME USERS OF OTHER VENDOR SERVICES,  
SOMEWHAT REDUCING THE MARKET BURDEN ON NASA

OSS 7997  
10/28/87



## BASIC ISSUES

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- NASA and the international partners are the market for commercial services -- requires recognition by both NASA and the potential provider
- Commercial activity must be a definable business, not a piece of hardware
- Commercial companies consider a franchise essential - they will compete for the franchise but it must be granted for sufficient time to allow recovery of costs (given performance)
- Commercial companies will need protection from delays, changes in requirements and cancellation
- International agreements can be a problem in this area if steps are not taken early to allow freedom of action

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10/27/87

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## SOME SPECIFIC BUSINESS ISSUES

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- Ownership - What do they own and how can/do they control their assets which are part of the Station
- Liability - Third party liability caused by accident or other action - will NASA support
- Specification - Safety, performance and interface requirements must be set and not changed to allow economical/manageable construction and known expenditure levels
- Performance - What are the penalties for non-performance of commercial service with NASA requirements/conversely, what will NASA pay in penalties for delay/non-performance caused by NASA
- Regulatory - Do terrestrial regulatory restriction on ownership (monopoly/anti-trust), ownership structures, environmental, work place rules, union rules, etc, apply on Space Station -- if not, who obtains waivers/clearances
- Pricing Policies - What price should the commercial venture pay for NASA provided services such as astronaut time or data management services

OSS 7999  
10/27/87

## GENERAL BUSINESS ISSUES

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- Properly structured, the deal should be no different from a normal business opportunity - there is interest there if this can be done
- Industry will be fearful of the opportunity because:
  - It will not be viewed as their traditional line of business
  - Working with NASA is new and has perceived risks (changes, government "red tape", etc.)
- Industry will be driven toward the opportunity because:
  - It shows profit potential if the proper deal can be devised
  - It provides entree into a new market area at its start with added benefits from high tech spin offs and public relations
  - Risks can be defined and, with proper contractual documents and other standard business arrangements, can be managed

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10/27/87

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## INDUSTRIAL SERVICES PANEL SUMMARY

### OPENING PLENARY SESSION

1. The Industrial Services panel plenary session provided the participants with overview information in the three areas for potential commercial services: On-orbit services, Transportation services, and Ground services. Dr. Earle Huckins (Director, Strategic Plans and Programs Division, Office of Space Station) stated that the panel goal for the workshop was to "Identify potential Space Station service opportunity concepts and related issues and business considerations."

Prior to the Workshop the panel met and identified the following Industrial Services market areas:

- On-Orbit Services
  - Platform/Free Flyer;
  - Power;
  - Space Structure Construction & Assembly;
  - Spacecraft Servicing;
  - Storage;
  - Communication;
  - Laboratory;
  - Health;
  - Hotel/Food/Logistics;
  - Waste Management;
  - Hazardous Debris Retrieval;
  - Data Management; and
  - Equipment Testing & Checkout.
- Transportation Services
  - ELVs;
  - Re-entry Systems;
  - OMV;
  - OTV; and
  - Shuttle.
- Ground Services
  - Logistics;
  - Payload Design & Processing;
  - Communication;
  - Tele-Science;
  - Data Management;
  - Training Simulators; and
  - Navigation.

2. During the beginning of the panel working session each of the sub-panel chairmen provided an overview of their respective areas:

- Mr. William Stoney (GE/RCA Astrospace) provided an overview of the On-orbit services area. Mr. Stoney defined what services constituted On-orbit services and gave some examples of potential services.
- Mr. David Rossi (Orbital Science Corporation) provided an overview of the Transportation services area. Mr. Rossi provided definitions of the various Earth orbits and the transportation services that would be required. Mr. Rossi defined commercial transportation opportunities as government contracting, commercialization, or privatization and discussed how each method would work.
- Mr. Robert Goss (Astrotech) and Mr. Anderson Bennett (JPL) provided an overview of the Ground Services area.

The panel then broke into three sub-panels to conduct working sessions in each of the industrial service areas.

## INDUSTRIAL SERVICES SUB-PANEL DISCUSSION SUMMARIES

### ON-ORBIT SUB-PANEL SUMMARY

#### On-Orbit Sub-Panel Participants

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Steve Stevenson	Aerospace Engineer	NASA - LeRC
Tom LaVigna	Project Manager for Space Station Service System	NASA - GSFC
W.E. Stoney	Manager	GE/RCA Astrospace
Chick Garcia	Business Develop- ment Manager	Grumman Corporation
Joe Angelo	Director-Advanced Technology	EG&G, Inc.
Donald J. Simkin	Director, External Integration	Rockwell International Space Station Division
Peter E. Glaser	Vice President	Arthur D. Little, Inc
Harvey J. Schwartz	Deputy Director of Inter-agency and Industry Programs	NASA - LeRC

Chuck Jacobus	Director, Cntr for Autonomous & Man-Controlled Robotic & Sensing Systems	ERIM
Ray Zuzinec	Director, Field Research	Snap-On Tools Corp.
Earle Huckins	Director, Strategic Plans and Programs, Office of Space Station	NASA Headquarters
Ray Askew	Director, CCDS in Power	Auburn University
Jerry Friefeld	Program Manager Space Station	Rockwell International Rocketdyne Division Advanced Development Westinghouse R&D
Chris Alexion Center	Senior Engineer	
Harry Andrews	President	Wespace, Inc.
Olav Smistad	Customer Integration	Space Industries, Inc.
Peter Stark	Program Manager	Center for Innovative
Technology		
Kenneth J. Demel	Customer Utilization Manager	NASA - JSC
John Egan	President	The Egan Group
Ronald S. Weinstein	M.D.C. Chairman	Corabi Telemetrics
George McCanless	Engineer	NASA - MSFC
R.K. Jacobson	President and CEO	Spacehab, Inc. D.C.
Joe Rutherford	Advanced Programs Manager	KMS Fusion, Inc. Houston
Jay Harnage	Manager, Space Commercialization	Grumman Space Systems Division
Ron Giuntini	Manager, Space Engineering and Hardware	Wyle Laboratories
P.D. Gerke	Manager External Integration	NASA - JSC
Bradley J. Schwartz	National Account Manager	Peat Marwick Main & Co.
Kevin Barquinero	Member, Technical Staff	NASA - Headquarters

1. During the Workshop, the On-orbit Services sub-panel discussed the opportunities and requirements for providing general Space Station support, in addition to the related issues and business considerations. More specifically, these support services include such viable market areas as power, waste processing, data management and transmission, food management, lodging accommodations, medical/health services, and environmental maintenance. While the sub-panel recognized these areas as possible service opportunities, the sub-panel also recognized that there were many institutional hurdles that had to be overcome in order for industrial service providers to get involved.



2. The sub-panel discussed the possible ways industrial service providers could get involved:

- A. Provide services that are currently being planned as part of the baseline.
- B. Provide supplementary services not currently included in the baseline that would augment the Station's capability.
- C. Provide services to accommodate growth during the evolution phase.

3. The discussion of general onboard services prompted many important issues and/or questions:

- What will the commercial entity own and how can they control their assets once they become a part of the Station?
- Will U.S. regulatory restrictions on ownership apply (monopoly/anti-trust)?
- Will NASA support third party liability insurance?
- Will safety/performance codes and standards be established and implemented?
- Will there be safety standardization?
- Will penalties for non-performance of commercial service and NASA service be established?
- What price will commercial ventures pay for NASA provided services? Who regulates?
- Who will be appointed as the regulatory/controlling agency, both domestically and internationally?
- Will OMB Circular A-76 tax and accounting procedures apply or can they be modified to be more advantageous to space ventures?

4. In order to overcome these obstacles to commercialization, NASA/U.S. Government will have to develop mechanisms to effectively accommodate private sector initiatives. The sub-panel suggested NASA could alleviate some commercial concerns by:

- Establishing concrete guidelines for the operation, servicing, and management of the Station;
- Modifying government purchase regulations or federal laws to fully fund multiyear contracts and provide acceptable termination protection to help promote long-term contracts (5 to 10 years) and NASA commitments, which will be required by private investment;
- Developing an accounting analysis system to provide for "true" comparisons in the government's make or buy decision and to provide accountability of the cost to NASA to support commercial ventures;
- Providing a zoning commission to handle system integration for add-on and growth services;
- Establishing a mechanism to announce available service opportunities, and then competing for exclusive rights to the "franchise";
- Offering proper "franchise" control; and
- Working with other government agencies to extend "space" patent laws to more than 17 years to allow for the longer product development times and investment recapture.



5. The sub-panel also mentioned potential candidates for commercialization in the areas of internal and external services. These services include:

- Laboratory facilities, equipment, personnel, and operations;
- Spacecraft servicing, assembly, and testing;
- Attached payload construction, operations, servicing, and management;
- Co-orbiting facility support; and
- Polar platform facility servicing and replacement.

6. The sub-panel agreed that the private sector must approach NASA now with their concepts for providing commercial services to ensure lasting industry involvement. The sub-panel believes commercial ownership and operation of some of the baseline systems and services may be effective ways to develop private interest in investing in the growth of the Space Station. However, it was also recognized that participation in the baseline system complicates integration and operations of the initial Station configuration. The sub-panel believes commercial investment is made possible because revenue streams can be relatively accurately forecasted from the baseline operation requirements and plans. Thus, industrial service opportunities could be made attractive if the right deal was negotiated with NASA. Effective incorporation of the proposed commercial activity will enhance and ensure the future growth of the civil space program and reduce NASA's capital investment in the program while increasing the capability of the Space Station. The sub-panel was encouraged by the program's recent actions in facilitating commercial participation in the program through the Space Station Commercial Users Policy and Guidelines and the language in the Phase C/D RFPs.

### TRANSPORTATION SERVICES SUB-PANEL SUMMARY

Transportation Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
David Rossi	Manager	Orbital Science Corp.
Donald Langreich	Manager, Commercial Space Programs	General Electric Corp.
Donald Palac	Manager	NASA - LeRC
Jeffrey Manber	Project Director	Dept. of Commerce
Ken Demel	Commercial Utilization	NASA - JSC
Fritz Runge	Manager, User Integration	McDonnell Douglas Astronautics Co.
Charles Anderson	Marketing Manager	Air Products and Chemicals, Inc.

1. The Transportation Services sub-panel discussed the existing capabilities and new commercial opportunities in space transportation. The sub-panel also discussed the requirements for future transportation to and from earth orbit, inter-orbit and intra-orbit.



The inter-orbit transportation requirements would be met with Expendable Orbit Transfer Vehicles (EOTV) and Re-usable Orbit Transfer Vehicles (ROTV). The intra-orbit transportation requirements will be met through the use of Orbital Maneuvering Vehicles (OMV) and Manual Maneuvering Units (MMU).

2. The sub-panel discussed the methods and barriers to commercializing space transportation and found that the barriers were more policy related as opposed to technology related. The sub-panel developed thirteen specific recommendations to facilitate commercialization:

- Purchase requirements rather than specifications - a total package approach. The sub-panel feels that NASA should purchase a service, such as "payload transportation to and from the Space Station," and not try to purchase a specific launch vehicle or hardware. The sub-panel also believes that this recommendation is easily implemented in space transportation.
- Lease re-usable space transportation services rather than developing and operating the technology - privatization of new or existing systems could be implemented. The sub-panel recommends that transportation services such as launch pads, payload processing, and transportation test facilities be privatized. This could also have a benefit in the near-term of reducing NASA personnel who could move into the private sector.
- Standardize risk versus cost analysis within NASA. The sub-panel noted that different NASA facilities calculate risk and cost analysis differently.
- Ease the process of accepting and acting on unsolicited proposals.
- Work for multi-year funding of space transportation procurements with minimum unit purchase guarantees. The sub-panel feels that this is necessary in order to encourage industry to make long-term capital investments.
- Waive FAR requirements that give NASA rights to proprietary technology information.
- Encourage the formation of consortia to undertake high risk commercial projects. The sub-panel recommends this approach because it would allow new companies to share the financial burden involved with this type of effort and it would bring the complimentary skills of many companies into the commercial venture.
- Create a space transportation "post office" that purchases all forms of space transportation to drive down the cost and to open the market.
- Establish NASA outreach programs to inform non-aerospace corporations about space transportation opportunities.
- Establish a "big brother" program between established aerospace firms and non-aerospace firms. The sub-panel recommends this program since non-aerospace firms are not familiar with the aerospace market, especially the NASA way of doing business. Moreover, since space transportation is viewed as the biggest commercial problem to solve. The sub-panel recommends that the transportation area should be addressed first.
- NASA should issue "idea patents" (internal and external) with an option payment to ensure credibility. The sub-panel recommends this action to solve the problem of companies approaching NASA with an idea, NASA taking that





idea and providing it to the competition. The implementation of this action would entail companies making a "down payment" on their ideas.

- Create a clearing house of potential projects that have been rejected for funding by traditional avenues. The sub-panel feels that many good ideas for potential projects are valid, but because the originator did not receive funding from NASA, they were not pursued. There may be a chance the projects could be funded and carried out commercially.
- NASA should ensure parity between commercial and government missions for licensing requirements.

3. The sub-panel identified the following four major barriers to commercializing space transportation:

- The government procurement process is long and cumbersome.
- NASA is resistant to change and is reluctant to accept non-NASA control of space assets. Control of assets is a key element of commercialized operations.
- NASA's strategic planning is adequate but not articulated to industry on a consistent basis. NASA should prepare long range strategic plans and identify technical thrusts. The plans should be distributed to industry so that companies can better plan their business in this area.
- Any product that will be marketed to non-NASA users must still have NASA's seal of approval.

4. The sub-panel generated the following three proposed services/ventures:

- Heavy Lift Launch Vehicle (HLLV) payload delivery system. The objective would be to develop a low-cost expendable vehicle to deliver payloads to the space station. (Alternatively, to sustain HLLV payloads until an OMV can get to them). Current HLLV concepts deliver payloads short of the planned Space Station orbit. Launching an OMV with each payload is a difficult challenge to OMV manifesting. A simple, cheap "throw away" delivery tug would ease demands on STS and OMV manifests. (Alternatively, if heavy lift, launch vehicle payloads are delivered to an OMV rendezvous orbit, it will take approximately 40 hours for the OMV to get there. An expendable "payload sustainer" could support payloads until OMV can get to them).
- Expendable Launch Vehicle (ELV) Logistics Carriers. The objective would be to develop the capability to deliver supplies (pressurized, unpressurized, propellants, and fluids) to the Space Station, and to return Space Station downloads. If ELV's are to be used for Space Station supplies, the supplies must be packaged more efficiently than the STS logistics module. Separate carriers may be required for the four categories of the Station supplies. Consideration must be given to providing an ELV-based return capability; otherwise, ELV's only make a bad download problem worse.
- Space Station Traffic Management System. The objective would be to ensure a safe flow of traffic to and from the Space Station, as well as being a final destination for many payloads. The Space Station will also serve as a

transportation node. An "air traffic control" capability may be required to maintain a safe, managed flow of vehicular traffic to, from, and around the Space Station. Some Space Station crew time would be required, but this system would exist in part to avoid surprises to the crew.

### GROUND SERVICES SUB-PANEL SUMMARY

#### Ground Services Sub-Panel Participants:

<u>NAME</u>	<u>TITLE</u>	<u>AFFILIATION</u>
Bill Wolfe	Technical Deputy Program Manager	G.E. Aerospace Division
Francis King	Research Engineer	Ford Motor Company
Peter Bishop	Director	Space Business Info. Center, UH-Clear Lake
Bruce W. Larsen	Manager	NASA - KSC
John Champagne	Director, Business Development	COMSAT
Fred Allamby	Manager	NASA - LaRC
Tom Bailey	Senior Systems Analyst	Tennessee Technology Foundation
Jeanne Hebein	Senior Project Specialist	United Airlines Services Corp.
Bart Cross	Senior Project Specialist	United Airlines Services Corp.
Jeffrey Grover	Senior Research Scientist	Georgia Tech Research Institute
Bill Holen	Manager	United Airlines Services Corp.
Mark Madamba	Director, Product Development Department	Ver-Val Enterprises, Inc.
Donald Smith	Manager	Cincinnati Milacron
Anderson Bennett	Member, Technical Staff	Jet Propulsion Lab
Andy Couch	Senior Consultant	Peat Marwick - Commercial Space Group

The Ground Services sub-panel discussed various service opportunities and developed 13 specific areas of opportunities with recommendations on ways to facilitate industrial involvement.

1. The Ground Services sub-panel discussed the use of robotics technologies for a variety of Space Station related functions. Use of robotics in lieu of humans or other mechanized processes offers advantages in efficiency, reliability, safety and could eliminate a need to



subject humans to unfavorable, unhealthy environments. Additional research in using robots in a zero-gravity environment could result in commercial applications to:

- Service the Space Station;
- Transfer Payloads;
- Conduct Experiments; or
- Service Craft Modules and Equipment.

The sub-panel recommends the Office of Commercial Programs (OCP) encourage development of zero-gravity robotics technology in the near term and that industry establish an agreement with OCP for this activity. The sub-panel also recommends OCP to encourage Commercial Uses of Space (CUS) activity in robotics workshops sponsored by NASA and other organizations in industry and government.

2. The sub-panel discussed the importance of data pertaining to the space station and the necessity for potential CUS participants to access that data. The sub-panel recommends that NASA permits commercial resale of Technical and Management Information System data with or without enhancements to assist potential users. The sub-panel recommends that the OCP meet with the Office of Space Station to discuss the potential marketing of this service.

3. The sub-panel discussed the potential splitting off of Space Station R&D and Operations responsibility. In doing so, NASA would retain R&D responsibility, while responsibility for operations would be transferred to a separate government or private entity. The sub-panel recommends that the OCP initiate discussions to explore the relative merits of establishing an operations agency or company.

4. The sub-panel discussed the requirements for processing hazardous materials at launch facilities. Hazardous residues will result from various experiments. Handling these materials require upgrades to NASA facilities or development of commercial capabilities. The sub-panel recommends that this function be identified as a potential commercial opportunity. The sub-panel will develop a top level requirements definition document which will be submitted to NASA by February 15, 1987.

5. The sub-panel discussed the potential development of a commercial capability to provide communications to and from ground and LEO via satellite. Presently, communications with Space Station are planned to be provided by TDRSS. This is expected to place a large burden on the TDRSS System. A large potential market exists for this service if TDRSS capacity is reached and as European and Japanese satellites become operational. This market is particularly attractive if all International Data Relay Satellites use the same spectrum and format. The sub-panel recommends that OCP meet with the FCC and major U.S. Satellite communications companies to explore the potential and develop a market strategy.

6. The sub-panel discussed potential development of a commercial capability to provide communications to and from ground to LEO via ground stations. NASA currently has no plans to provide ground station communications for Space Station, therefore, users who require this service cannot obtain it. The market potential for such a service is unknown.



The sub-panel recommends that NASA and the U.S. Telecommunications industry jointly explore the market potential and feasibility of communications to and from ground to LEO via ground stations.

7. The sub-panel discussed the requirement for an organization to assist users in the design and development of flight hardware and pre-launch/on-orbit operations planning. This is presently one of the anticipated functions of the planned Science and Technology Centers (STC). This necessary service is especially critical to companies who are new to the space industry. There could be a role for both NASA and commercial entities to play in providing the service. The sub-panel recommends that NASA recognize the commercial services option in operational planning. The sub-panel will develop a recommendation to the OCP, concerning NASA and industry roles by March 1, 1988.

8. The sub-panel discussed the requirement for an inventory of space qualified hardware components. This would allow those requiring hardware to find out where they can obtain it, at what cost and how long a lead time is required. The sub-panel will develop a top level requirements definition aimed at developing a preferred parts lists of space qualified components. This document will be presented to the OCP by February 15, 1988.

9. The sub-panel discussed the unique training requirements of Space Station, which differ greatly from previous NASA missions due primarily to:

- evolutionary nature of the system;
- diversity of training requirements; and
- scope of the program.

Throughout its life cycle, hundreds of people from varied backgrounds will live and work aboard the Space Station to perform a wide range of experiments and functions. This necessitates an integrated training approach, which presents a commercial opportunity NASA should consider. The sub-panel will develop a top level requirements definition document for presentation to the OCP.

10. The sub-panel discussed post-flight receiving and payload processing. As the number and type of experiments increase, there will be increased opportunities for commercial concerns to provide this service to Space Station users. Special facilities will be required to perform post-flight functions. In many cases, planned or existing NASA facilities can be used. A commercial opportunity exists to augment NASA capabilities. The sub-panel will develop a top level requirements definition document toward developing post flight receiving capabilities. This document will be presented to the OCP by June 15, 1988.

11. The sub-panel discussed the possible development of ship platform launch facilities for flight support. A ship platform launch capability would provide flexibility for launch location, could be placed to provide added launch safety, could possibly be used for recovery operations and introduces a number of unique, innovative techniques and advantages for launch recovery. A commercial opportunity exists to build and operate ship platform launch facilities. NASA should assemble a summary of literature on innovative launch facilities and outline the related technical concepts. NASA should then work with interested organizations to work out NASA/Space Station interfaces, communications, etc.



12. The sub-panel discussed possible commercial opportunities to provide "generic robotics" for Space Station use. Many experimenters aboard Space Station may not have "in-house" skills to develop their own space qualified robots. A commercial opportunity exists to provide generic, adaptable robots for experimentation purposes. The sub-panel recommends that the NASA Goddard Space Flight Center facilitate the establishment of generic standards and interface requirements for Space Station robotics and tools.

13. The sub-panel discussed possible commercial opportunities for pre-launch and payload integration. In the past, most pre-launch payload processing and payload integration functions have been performed in NASA operated facilities at the launch site. A commercial opportunity exists to take on all or part of these operations on a commercial basis, partly through the privatization of functions presently performed by the government. The sub-panel will develop a proposal and present it to OCP by June 15, 1988, regarding functions which could be privatized and agreements which must be formalized regarding activity operations, takeover, liability and other matters.

### **CLOSING PLENARY SESSION**

1. The Industrial Services panel met to receive the reports from the three sub-panels. The reports were summaries of the sub-panel discussions and issues/recommendations generated.

2. The On-Orbit Services sub-panel report consisted of endorsement/identification of potential commercial on-orbit services opportunities, business and policy issues that need to be addressed, and some general recommendations. The potential candidates for commercialization include: lab space, spacecraft servicing, attached payload management, co-orbiting facilities, polar platform facilities, facility support, and personnel support. Some important issues and business considerations were discussed including: ownership definition, liability, specification, performance guarantee, regulatory issues, pricing policies, contractual issues, and international issues. The sub-panel concluded:

- The private sector should approach NASA now with their concepts for providing commercial services for both the baseline and growth Space Station;
- NASA should develop mechanisms to effectively accommodate private sector initiatives; and
- Effective incorporation of commercial activity on the Space Station will significantly enhance and ensure the future growth of the civil space program.

3. The Transportation Services sub-panel report recommended 13 specific actions to facilitate space commercialization, identified several barriers to commercializing space transportation, and proposed three new services/ventures.

- Purchase requirements rather than specifications - a total package approach. Easily implemented in space transportation.



- Lease re-usable space transportation services rather than developing and operating the technology - privatization of new or existing systems could be implemented.
- Standardize risk vs cost analysis within NASA.
- Ease the process of accepting and acting on unsolicited proposals.
- Work for multi-year funding of space transportation procurements with minimum unit purchase guarantee.
- Waive FAR requirements that give NASA rights to proprietary technology information.
- Encourage the formation of consortia to undertake high risk commercial projects.
  - shares financial burden
  - brings complimentary skills
- Create a space transportation "post office" that purchases all forms of space transportation to drive down the cost to open the market.
- Establish NASA outreach program to inform non-aerospace corporations about space transportation opportunities.
- Establish "big brother" program between established aerospace firms and non-traditional firms.
- NASA should issue "idea patents" (internal and external) with an option payment to ensure credibility.
- Create a clearing house of potential projects that have been rejected for funding by traditional avenues.
- NASA should ensure parity between commercial and government missions for licensing requirements.

The sub-panel identified the barriers to commercializing space transportation services as:

- The government procurement process is cumbersome.
- NASA is resistant to change and is reluctant to accept non-NASA control of space assets.
- NASA's strategic planning is adequate and not articulated to industry on a consistent basis.
- Any product that will be marketed to non-NASA users must have NASA's seal of approval.

The sub-panel concluded that to increase industrial participation in the Space Station:

- NASA must expand participation by the existing aerospace and related community; and
- Enhance assurances to space access.

4. The Ground Services sub-panel report consisted of the following 13 identified potential commercial opportunities:

- Robotic applications for servicing Space Station
- Commercially provided TMIS's access service
- Space Station operations by a commercial entity



- Hazardous materials processing at launch site
- Commercially-provided communications from ground and LEO via satellite
- Commercially- provided communications to and from ground to LEO via ground stations
- Design and development of flight hardware
- Inventory of "space qualified" hardware components
- Integrated training
- Post flight receiving
- Flight support - development of ship platform launch facilities
- "Generic" robotics for Space Station experiment use
- Pre-launch payload processing and integration

The panel concluded that many of these opportunities are currently being planned as NASA owned and operated services, yet they could be privatized or commercialized. However, it was not the panel's intent to recommend at this time which opportunities were better suited for privatization. Their intent was just to identify the scope of opportunities for NASA and industry to consider. There was genuine interest amongst the participants in giving serious consideration to privatization/commercialization of these services/systems. Because the concepts are novel and the brevity of time available at the Workshop, the mechanisms to implement these concepts were not formalized.





**SECTION IV**

**WORKSHOP SUMMARY AND  
RESULTS**





Space Station

Commercial Users Workshop

# WORKSHOP SUMMARY AND RESULTS

## SPACE PANEL REPORTS

## CONCLUSIONS, RECOMMENDATIONS, AND ACTIONS



## SPACE DISCIPLINE PANEL REPORTS

Each Space Discipline Panel presented a report of their findings. Summary presentations of the sub-panel discussions were given. This section contains the summary vugraphs presented. The order of presentation was:

### Industrial Services

- On-Orbit Services (No vugraphs)
- Transportation Services
- Ground Services

### Materials Processing in Space

- Polymers
- Combustion
- Glasses and Ceramics
- Biotechnology
- Metals and Alloys

### Earth and Ocean Observation

- Renewable Resources
- Advanced Applications
- Non-Renewable Resources

## Space Transportation Services Sub-Panel

To increase industrial participation in the Space Station, NASA must first expand participation by the existing aerospace and related community.

Before industrial participation of the Space Station can be expanded, assured access to space must be enhanced.

## Space Transportation Services Sub-Panel

### Specific Recommendations

1. Purchase requirements rather than specifications - a total package approach. Easily implemented in space transportation.
2. Lease re-usable space transportation services rather than developing and operating the technology - privatization of new or existing systems could be implemented.
3. Standardize risk vs cost analysis within NASA.
4. Ease the process of accepting and acting on unsolicited proposals.
5. Work for multi-year funding of space transportation procurements with minimum unit purchase guarantee.
6. Waive FAR requirements that gives NASA rights to proprietary data.
7. Encourage the formation of consortia to undertake high risk commercial projects.
  - shares financial burden
  - brings complementary skills
8. Create a space transportation "post office" that purchases all forms of space transportation to drive down the cost and open the market.
9. Establish NASA outreach program to inform non-aerospace corporations about space transportation opportunities.
10. Establish "big brother" program between established aerospace firms and non-traditional firms.
11. NASA should issue "idea patents" (internal and external) with an option payment to ensure credibility.
12. Create a clearing house of potential projects that have been rejected for funding by traditional avenues.
13. NASA should ensure parity between commercial and government missions for licensing requirements.

## Space Transportation Services Sub-Panel

### Barriers to Commercialization

1. The government procurement process is cumbersome.
2. NASA is resistant to change and is reluctant to accept non-NASA control of space assets.
3. NASA's strategic planning is adequate but not articulated to industry on a consistent basis.
4. Any product that will be marketed to non-NASA users must have NASA's seal of approval.

## Ground Services Sub-Panel

1. Robotic applications for servicing Space Station.
2. Commercially provided TMI's access service.
3. Space Station operations by a commercial entity.
4. Hazardous materials processing at launch site.
5. Commercially provided communications to and from ground and LEO via satellite.
6. Commercially provided communications to and from ground to LEO via ground stations.
7. Design and development of flight hardware.
8. Inventory of "space qualified" hardware components.
9. Integrated training.
10. Post flight receiving.
11. Flight support - development of ship platform launch facilities.
12. "Generic" robotics for Space Station experiment use.
13. Pre-launch payload processing and integration.

## Materials Processing in Space

### Issues

- Status of research
- JEA processing
- Access to space
- Free-flyers
- Proprietary rights
- Need for FDA involvement (Biotechnology)
- Tax incentives
- Operational concerns
- Onboard analysis and systems
- Safety
- MRDB
- Other agencies involved
- Need for NASA support for up-front industrial research
- Small business

## Material Processing in Space Panel

- Need for precursor experiments. (Polymers)
- Access to space - Electronic Materials group stressed need for free-flyer (constant "g" level without perturbations).
- Proprietary rights.
- Need for FDA involvement. (Biotechnology)
- Trade-offs - onboard vs. quick return to Earth. (Biotechnology)
- NASA needs to support industrial research up front, especially with small companies.
- Polymers - 4 specific, proof-of-concept experiments - look at non-Newtonian fluid physics.
- Need for data base of unexpected phenomenon of results. (Combustion)
- A more narrowly focused workshop for Materials Processing in Space.
- Metals and Alloys - number of experiments identified - problem of time length to process a JEA.

## Polymers Sub-Panel

### Recommended Basic Polymer MPS Experiments:

1. Extensional Viscosity Measurements in Microgravity.
2. Basic Polymerization Reaction in Diffusion Controlled Environment.
3. Spinoidal Decomposition.
4. Structural Foam Production.
5. Drop-Breakup of Polymer Solutions.

### Recommendations:

1. Urge existing polymer MPS experiments be flown.
2. Fluid physics group to do non-Newtonian fluids, polymer fluids and solutions:
  - Drop Break-up
  - Drop Coalescence



## Combustion Sub-Panel

- NASA's role in commercial developments in combustion is to provide a substantial data base of fundamental phenomena from which unexpected results will appear. These unexpected results act as seeds for the germination of innovations in ground-based processes and some spacecraft applications (most likely in safety related areas) the likelihood of spin-offs is high.
- The modular combustion facility approach to Space station combustion research is appropriate. The list of reference experiments currently being used is good, but should include provision for metals combustion.
- The principal driver for station combustion experiments will probably be the consumables flow through - supplies of consumable gases and disposition of wastes. NASA should support development of recycling technology, such as "membrane separation technology"

### Questions:

- How will the concepts and requirements for the modular combustion facility be included in the data base, and how will it be periodically made available to academic and industrial researchers for review and update?

## Glasses and Ceramics

### Sub-Panel

3 to 5 Industry Participants, 8 to 12 Total

#### Gaps in Science Base

- |          |   |   |
|----------|---|---|
| Glasses  | - | fiber pulling - equipment gap               |
|          | - | phase separation                            |
|          | - | hollow sphere formation                     |
| Ceramics | - | fiber growth via float zone - equipment gap |

#### Hardware Gaps

Adequate glove box facilities connected with combustion and fluids for CVD and Gas Phase Synthesis

#### Analysis Equipment

Scanning Electron Microscopy vs. Space Main (Sample Return)

#### Issues/Obstacles

- Flight opportunities
- How to get aboard program still a mystery
- Insufficient industry participation in:
  - setting of science priorities
  - equipment priorities
- Workshop: Too broad to serve materials subdisciplines  
Need more narrowly focused workshop to draw out more industry participation
- Timeliness from idea to flight given concerns about toxicity, particles, pressure vessels, and process of implementing.

## Biotechnology Sub-Panel

### Business Issues

#### Incentives

- National Space Biotechnology Laboratory concept
- Tax incentives
- Protection of proprietary rights
- FDA participation (need to bring FDA input to planning)
- Technical advantages through cooperative research activities, multidiscipline research, and marketing opportunities via NASA-related companies.
- Spread the risk

#### New Proposals

- Innovation through CCDS's

Critique of new ideas - Advances in the status of "Biotechnology" and "Biotechnology Community" needs in Space Station EVA cannot be accurately estimated. New diagnostic capabilities, research techniques, therapies, etc.

## Biotechnology Sub-Panel

### Space Station Facility Issues

The emphasis should be on requirements rather than an individual facilities

1. Study of macromolecular crystallization aggregation, synthesis and assembly.
2. Cellular level studies, secretion, multiplication, interaction and differentiation.
3. Separation, purification, and fractionation of particles and (macro) molecules.
4. Integrated analytical systems for: (macro) molecules, chemical products and cells.
5. Essential support: waste handling sterilization, environmental health and safety, water quality and quantity.

## Metals and Alloys Sub-Panel

### Proposed Areas of Interest

- Porous Foam - Hollow Spheres
  - Composite Alloys - Wetting
  - Precious Metal Catalysts
  - Melt Purification
  - Metals and Alloys Characterization
- ALCOA, YIN
  - ABEX
  - Engelhard
  - Engelhard
  - Energy Technology Consultants

### Participants:

- 5-6 industrial
- 6-7 NASA/Academic

### Issues:

Time differences to obtain JEA - 3M versus Grumman experience  
High Temperature Furnace Facility ( $>2000^{\circ}\text{C}$ )

## Renewable Resources Sub-Panel

### Objectives

- Review MRDB parameters and match user requirements against planned remote sensing missions.
- Evaluate the potential user of EOS for developing commercial applications.
- Seek new mission requirements.

## Renewable Resources Sub-Panel

### Background

- Polar platform provides a significant commercial remote sensing opportunity for renewable resources.
- Space Station can serve agriculture, forestry, fisheries and mapping among others.

### MRDB Review

- No requirements for instrument test facility on the core station at this time.
- Requirements for core mounted SSAR can be met with EOS SAR.
- Large Format Camera requirements remain valid.
- Enhanced Thematic Mapping requirements remain valid.

## Renewable Resources Sub-Panel

### Issues:

- NASA should inform the community of commercial opportunities on the Polar Platform
- Timeliness of data
  - Value of data for many RR applications degrades rapidly
- Repeat coverage
  - Repeat cycle inadequate for many applications
  - Pointable sensors are important
- Platform stability capable of meeting U.S. National map accuracy standards
- Data rate prioritifies (Commercial/Operational/Research) X-band requirement

### Advanced Applications Sub-Panel

- Policy is as important as technical issues
  - Codes C, E, and S should coordinate
- Follow-on to action items be reported at next conference

#### Policy issues:

- Priority access to resources
- Servicing
- Direct downlink to user
- Cost/Pricing information
- Spatial resolution
- Government/industry cost sharing
- Industry input to NASA definition
- 28<sup>0</sup> platform for sensor development-radar
- Analog data on polar platform
- Direct downlink
- Early input to geostationary platform

### Non-Renewable Resources Sub-Panel

- I. Issues
1. Role of Government vs. Industry
  - Conduct of experimental activities and competition with potential commercial ventures
2. Concern by users about reliance and planning for polar platform as "sole" NASA experimental spacecraft
  - Single point failure, budgetary realism
3. Competition for platform resources
4. Need for continuing mechanism for industry/government interaction for space policy
  - Data access vs. proprietary rights

### Non-Renewable Resources Sub-Panel

- II. Near-term opportunities
  - 1. Large format camera
    - Questionable commercial value (28° inclination orbit)
  - 2. Radar
    - Commercial (L-band, HH, 25° Dep. Angle, 100km swath, polar orbit, digital)

### Non-Renewable Resources Sub-Panel

- III. Research opportunities/needs
  - 1. Radar
    - Experimental (multi-frequency, multi-polarization variable depth angle)
  - 2. Precision laser altimetry
    - Experimental (high resolution registered optical imagery (lars))
  - 3. Multispectral thermal IR
  - 4. Narrow-band imaging spectrometer
    - Tuneable bands and bandwidth (5nm)
  - 5. Passive fluorescence detection research
  - 6. Detection of hydrocarbon seeps and spills (off-shore and on land)
  - 7. Parametric evaluation of solar illumination angle and plane of incidence
  - 8. Capability for ice monitoring
    - To support non-renewable resource development
  - 9. Precision topographic mapping capability
  - 10. Gravity satellite

## Non-Renewable Resources Sub-Panel

### Specific MRDB Comments

1. COMM 1014
  - Remote sensing test, development, verification facility on-board core station
  - Parameters look reasonable -- supported by panel
2. COMM 1015
  - Large format camera
  - Parameters reasonable
  - Low priority because of orbital limitations and film media
3. TDMX 2261
  - Technological development facility for components of future sensors
  - No comment
4. TDMX 2262
  - Develop manned observational techniques
  - Use to support basic research and technology development
5. TDMX 2264
  - Passive microwave sensor development
  - Lower priority
  - Useful for study of ocean currents

### Specific MRDB Comments

6. SAAX 220
  - Data collection/location platform
  - Need on polar platform and core station
7. SAAX 251
  - Tropical rainfall mapping
  - Weather for operations planning
  - Also, climate and global
8. COMM 1019
  - Commercial electrical optical imagers
  - MRDB high priority timing needs revision
9. COMM 1020
  - COMM SAR
  - High priority for both operations and research
10. COMM 1023
  - Commercial ocean color imager
  - Supports high priority areas of research in detecting hydrocarbon seeps, current monitoring, silica deposition
11. SAAX 202
  - EOS on polar platform
  - Very high priority  
(see issues re: budgetary reality, single mission concept, commercial competition)

SAXX	High	Medium	Low	Comments
208 MODIS T	X			
209 HIRIS	X			
210 AMSR		X		
213 AIR(RADAR)		X		For GEOID/Gravity
214 Scat.		X		Current & sea state info. for operations
215 Corr. Radiom			X	Not clear to panel how it could apply
220 Auto data collection	X			" "
233 Sub MM Spect			X	" "
234 Pressure Mod. Radiom.			X	" "
235 IR Radiom.			X	" "
236 LAWS			X	" "
238 Radar Climate Interferometer			X	" "

SAXX	High	Medium	Low	Comments
239 Modis-N	X			
240 Micro. wave Imager			X	
241 GL(A)RS	X			Laser altimetry "(A)" also high priority
242 LASA			X	" "
243 Thinned array radiom.			X	High priority for GLRS applications
245 Precise Pos. Inst.		X		
246 MAG	X			
247 Magnetospher particle detector			X	
249 Payload Executive	X			



The reference letter (P, Par.2) refers to the Subpanel section discussion.

Space Station   
Commercial Users Workshop

## SPACE STATION WORKSHOP RESULTS RECOMMENDATIONS AND ISSUES

The workshop results have been placed into 5 categories:

- M -- MRDB Recommendations. Those that would necessitate changes to the MRDB (additions, deletions, modifications).
- R -- Research Recommendations. Areas or topics the panels recommended research or science programs be conducted.
- F -- Facility Recommendations. Those to upgrade or develop NASA or commercial facilities.
- N -- NASA Issues. Issues NASA need to address.
  - I -- In-House. Issues resolvable within NASA.
  - E -- External. Issues requiring coordination with agencies external to NASA.
- C -- Commercialization/Privatization Recommendations. Those dealing with issues and requirements to facilitate commercialization/privatization.

### MATERIALS PROCESSING IN SPACE

#### Polymers

- 1 (R) NASA should sponsor precursor polymer experiments in the following areas :
  - Measurements of extensional viscosity in microgravity (P, Par. 2);
  - Spinoidal decompositions (P, Par. 2);
  - Copolymerization of monomers with varying reactivity ratios. (P, Par. 2); and
  - Effects of microgravity on polymer foam production (P, Par. 2).
- 2 (R) NASA should fly the existing MPS polymer experiments (P, Par. 5) .
- 3 (R) The fluid physics group should do non-Newtonian fluids experiments to study (1) drop break-up and (2) drop coalescence (P, Par. 5).

#### Metals & Alloys

- 4 (M) NASA should place a high temperature ( $>2000^{\circ}\text{C}$ ) furnace facility onboard the station for metals and alloys work. (MPS Closing PLenary, Par. 3)
- 5 (R) NASA should perform research in the following areas: (MPS Closing Plenary, Par. 3)
  - Porous Foam - Hollow Spheres.
  - Composite Alloys - Wetting.
  - Precious Metals Catalysts.
  - Metals and Alloys characterization.

**Biotechnology**

- 6 (R) The biotechnology panel recommends placing more emphasis on meeting requirements rather than individual facilities -- especially related to:
- The study of macromolecular crystallization aggregation, synthesis and assembly (B, Par.2);
  - Cellular level studies: secretion, multiplication, interaction, and differentiation (B, Par. 3); and
  - Separation, purification, and fractionation of particles. (B, Par. 4)
- 7 (I) NASA needs to provide essential support such as waste handling, environmental health and water. (B, Par. 6)
- 8 (C) NASA needs to examine various incentives and business issues (B, Par. 7 and 9)
- The National Space Biotechnology Laboratory concept;
  - Tax incentives;
  - Protection of proprietary rights for existing space technology and future technological gains from space research;
  - Getting early FDA participation to help bring a space product at least to the head of the queue;
  - The technical advantages through cooperative research activities;
  - Multi-discipline research and marketing opportunities via NASA-related companies;
  - The incentive to spread the risk, which is the whole purpose of research; and
  - New proposals with innovation through the Centers for the Commercial Development of Space.
- 9 (F) NASA should have an integrated analytical system onboard the Space Station that allows module changes as requirements change. (B, Par. 5)

**Combustion**

- 10 (M) NASA should include provisions for metals combustion in the list of reference experiments currently being used. (C, Par. 2)
- 11 (R) NASA should support development of recycling technology such as "membrane separation technology". (C, Par. 3)
- 12 (I) NASA needs to explain how the concepts and requirements for the modular combustion facility will be included in the MRDB and how the MRDB will be periodically made available for review. [concern over access to MRDB] (C, Par. 2 and 4)
- 13 (N) NASA needs to provide a substantial database of low-gravity combustion phenomena to increase understanding of these phenomena and to inspire innovative ideas. (C, Par. 1)

**Glasses & Ceramics**

- 14 (R) NASA should conduct basic research in glass fiber pulling. Industrial interest in glass fiber pulling cannot realistically be expected until some basic research has been conducted and some success is demonstrated. (GC, Par. 1)
- 15 (C) NASA should expand industry input in the glass and ceramic area by sending a mailing of current research to industry and initiating a following up program. (GC, Par. 2)
- 16 (M) A dedicated material science glove box is a "wished-for" entity on the Space Station. The powder press is not important in the early stages. (GC, Par. 4)
- 17 (I) NASA and industry need more discussion to resolve waste handling and waste segregation for both toxic and non-toxic wastes. [Who has the responsibility?] (GC, Par. 5)
- 18 (R) The NASA fluid physics discipline team should encompass chemical vapor deposition and sputtering (coating studies) aspects of microgravity research in their work. (GC, Par.6)
- 19 (M) NASA needs to provide reliable and rapid sample retrieval or additional space and equipment in the Space Station will have to be dedicated for generic characterization studies. (GC, Par. 7)
- 20 (F) NASA needs to provide an onboard SEM with X-ray Fluorescence for rapid experiment analysis. (GC, Par. 7)
- 21 (C) NASA should investigate large scale space production of glass and polymer spheres. (GC, Par. 8)
- 22 (R) The MSAD fluid physics team should perform the chemical vapor deposition coating studies. (GC, Par. 8)

**Electronic Materials**

- 23 (F) NASA should establish a powered free flier. (EM, Par. 1)
- 24 (F) NASA should develop a Space Ultra-vacuum Research Facility. (EM, Par. 1)
- 25 (F) NASA should create a "National Special Characterization Facility." (EM < Par. 1)
- 26 (I) NASA should review and improve current peer review procedures. (EM, Par. 2)
- 27 (I) NASA should deal with research funding for industry as a separate unit. (EM, Par. 2)



- 28 (I) NASA should not consider industry proposals competitive with those from academia. (EM, Par. 2)
- 29 (I) NASA should facilitate participation of "small business" in the space program. (EM, Par. 2)
- 30 (I) NASA should improve JEA processing procedures. (EM, Par. 2)
- 31 (I) CCDS's need to be useful for a wider variety of needs. (EM, Par. 2)

## **EARTH AND OCEAN OBSERVATION**

### **Advanced Applications**

- 32 (C) NASA Code C should task someone to understand and identify market applications for pointable radar as a partial solution to data frequency and stereo needs on both the 28<sup>0</sup> platform and the polar platform. (AA, Par. 1)
- 33 (R) NASA and industry should identify mechanisms to encourage combined radar and visible imaging development for the 28<sup>0</sup> platform. (AA, Par. 2)
- 34 (I) NASA Code S should identify the pricing elements (costs and criteria for costs) for platform services. (AA, Par. 3)
- 35 (M) NASA should add a new mission to the MRDB for a ground/ice probing radar. (AA, Par. 4)
- 36 (I) NASA needs to form an earth and ocean observations sub-group of the National Association of Space Station Applications and Utilization (NASSAU) to feed into the NASA "system" and to enhance NASA's understanding of industry's motivations and operations. (AA, Par. 5)
- 37 (M) NASA needs to provide regulations and technology to allow a direct protected downlink to users from the platforms, and include this downlink in the MRDB. (AA, Par. 6)
- 38 (C) NASA should examine the possibility of allowing the direct downlink to be done commercially. (AA, Par. 6)
- 39 (E) The U.S. Government should clarify or modify current policy limiting satellite imaging data spatial resolution to enable U.S. companies to compete internationally. (AA, Par. 7)
- 40 (M) NASA should maintain the place holder mission (TDMX 2262) for manned observations. (AA, Par. 8)



- 41 (M) NASA should support COMM 1014 (Remote Sensing Test , Development, and Verification Facility) and ensure that it has a pointing capability. (AA, Par. 8)
- 42 (M) NASA needs to examine the current polar platform servicing schedule. The current schedule is unacceptable. A proposed solution is to provide redundant sensors on the ESA as insurance. (AA, Par. 9)
- 43 (E) NASA must ensure that industry has the opportunity to access non-U.S. platforms. (AA, Par. 9)
- 44 (I) NASA should provide industry with a policy for priority access (What are the criteria?) to the polar platform and 28<sup>0</sup> platform resources, including TDRSS. (AA, Par. 10)
- 45 (C) NASA should conduct future CEO level workshops on business and policy issues. (AA, Par. 10)
- 46 (I) NASA needs to commit early to the Geostationary (GEO) platform to support industry in the technology development required to deliver continuous real-time data capability that many advanced applications will require. Industry should be included on the GEO platform planning committees. (AA, Par. 11)
- 47 (I) NASA should explore Government/Industry sharing of instrument and data costs. (Addressing proprietary rights and co-funding issues). (AA, Par. 13)
- 48 (M) NASA should add the capability to provide analog data from both the 28<sup>0</sup> (electronic and film) and the polar platforms (electronic). (AA, Par. 13)
- 49 (C) Establish a commercial analog data relay capability. (AA, Par. 13)

#### **Renewable Resources**

- 50 (M) NASA should incorporate several key requirements for commercial users into the specifications of mission parameters. These issues include data rates and priorities of data rates from the platforms, repair priorities and schedules, provisions for direct data downlink, and information on additional commercial opportunities. (RR, Par.2)
- 51 (M) NASA should revise the MRDB for the LFC mission time frame and to correct spatial resolution from 14x25m to a 10 x 10m manageable size. (RR, Par. 3)
- 52 (M) NASA should revise the MRDB to include an attachment for a pointable LFC mount. (RR, Par.3)
- 53 (M) NASA needs to increase the OCI spatial resolution in the region where MODIS is lacking from 500m to 200-300m to perform all imaging activities. (RR, Par. 3)



## Non-Renewable Resources

54 (R) NASA needs to consider 10 areas of research opportunities in the non-renewable remote sensing area listed below. (NR, Par. 3)

- (1) Experimental radar with multi-frequency, multi-polarization variable depression angles.
- (2) Experimental precision laser altimetry with high resolutions registered optical imagery (GLARS).
- (3) Multispectral thermal IR.
- (4) Narrow-band imaging spectrometer with tunable bands and bandwidth (5mm).
- (5) Passive Fluorescence detection research.
- (6) Detection of hydrocarbon seeps and spills (offshore and on land).
- (7) Parametric evaluation of solar illumination angle and plane of incidence.
- (8) Capability for ice monitoring to support non-renewable resource development.
- (9) Precision topographic mapping capability.
- (10) Gravity satellite.

## INDUSTRIAL SERVICES

### Transportation Services

- 55 (C) NASA should specify transportation service requirements (Example, put an object into orbit) rather than specific hardware and configurations. Use a total package approach. (T, Par. 2)
- 56 (C) NASA should lease re-usable space transportation services rather than developing and operating the technology - privatization of new or existing systems could be implemented. (T, Par. 2)
- 57 (I) NASA should standardize risk vs cost analysis within NASA. (T, Par. 2)
- 58 (I) NASA should ease the process of accepting and acting on unsolicited proposals. (T, Par. 2)
- 59 (I) NASA should promote multi-year funding of space transportation procurements with minimum unit purchase guarantee. (T, Par. 2)
- 60 (I) NASA should waive FAR requirements that gives NASA rights to proprietary data. (T, Par. 2)
- 61 (C) NASA should encourage the formation of consortia to undertake high risk commercial projects. (T, Par. 2)
- 62 (C) NASA should create a space transportation "post office" that purchases all forms of space transportation to drive down the cost and expand the market. (T, Par. 2)



- 63 (C) NASA should establish an outreach program to inform non-aerospace corporations about space transportation opportunities. (T, Par. 2)
- 64 (C) NASA should establish a "big brother" program between established aerospace firms and non-aerospace firms. (T, Par. 2)
- 65 (I) NASA should issue "idea patents" (internal and external) with an initial option payment to ensure that the company is credible and committed to the idea. "Idea patents" would protect proprietary ideas presented to NASA for consideration to be later put out as a competitive RFP. (T, Par. 2)
- 66 (I) NASA should create a clearing house of potential projects that have been rejected for funding by traditional federal funding avenues. (OMB turns down a NASA project) These projects could be pursued by industry. (T, Par. 2)
- 67 (E) NASA should ensure parity between commercial and government requirements for mission licensing agreements. (T, Par. 2)
- 68 (I) NASA should include commercialization goals in the performance evaluations of NASA employees. (T, Par. 2)
- 69 (I) The Government procurement process is long and cumbersome. NASA should seek ways to improve this process. (T, Par.3)
- 70 (I) NASA should be more receptive to change and accept non-NASA control of space assets. Control of assets is a key element of commercialized operations. (T, Par.3)
- 71 (I) NASA's strategic planning is adequate but not articulated to industry on a consistent basis. NASA should prepare long range strategic plans and identify technical thrusts. The plans should be distributed to industry so that companies can better plan their business in this area. (T, Par.3)
- 72 (C) Any product that will be marketed to non-NASA users must still have NASA's seal of approval. (T, Par.3)

#### **Ground Services**

- 73 (R) The Office of Commercial Programs (OCP) should encourage development of zero-gravity robotics technology in the near term and establish an agreement between industry and OCP for this activity. (GS, Par. 1)
- 74 (C) OCP should encourage Commercial Uses of Space (CUS) activity in robotics workshops sponsored by NASA and other organizations in industry and government. (GS, Par. 1)
- 75 (I) OCP should discuss the potential marketing of TMIS access service with the Office of Space Station. (GS, Par. 2)



- 76 (C) OCP should initiate discussions to explore the relative merits of establishing a Space Station operations agency or company. (GS, Par. 3)
- 77 (C) NASA should develop a top level requirements definition document for hazardous materials processing at launch sites. The sub-panel will submit recommendations to NASA by February 15, 1988. (GS, Par. 4)
- 78 (C) NASA should meet with the FCC and major U.S. Satellite communications companies to explore the potential and develop a market strategy for commercial capability to provide communications to and from ground and LEO via satellite. (GS, Par. 5)
- 79 (C) NASA and the U.S. Telecommunications industry should jointly explore the market potential and feasibility of communications to and from ground to LEO via ground stations. (GS, Par. 6)
- 80 (I) NASA needs to recognize the commercial services option in operational planning. The Ground Services sub-panel will develop a recommendation to the OCP, concerning NASA and industry roles by March 1, 1988. (GS, Par. 7)
- 81 (C) The Ground Services sub-panel will develop a top level requirements definition aimed at developing a preferred parts lists of space qualified components. This document will be presented to the OCP by February 15, 1988. (GS, Par. 7)
- 82 (C) The Ground Services sub-panel will develop a top level requirements definition document for integrated training for presentation to the OCP. (GS, Par. 9)
- 83 (C) The sub-panel will develop a top level requirements definition document toward developing post flight receiving capabilities. This document will be presented to the OCP by June 15, 1988. (GS, Par. 10)
- 84 (C) NASA should assemble a summary of literature on innovative launch facilities and outline the related technical concepts and work with interested organizations to work out NASA/Space Station interfaces, communications, etc. (GS, Par. 11)
- 85 (I) NASA Goddard Space Flight Center should facilitate the establishment of generic standards and interface requirements for Space Station robotics and tools. (GS, Par. 112)
- 86 (C) The Ground Services sub-panel will develop a proposal and present it to OCP by June 15, 1988, regarding functions which could be privatized and agreements which must be formalized regarding activity operations, takeover, liability and other matters. (GS, Par. 13)
- 87 (C) NASA needs to develop a ship based platform launch facility. (GS, Par. 11)





### **On-Orbit Services**

- 88 (I) What will the commercial entity own and how or can they control their assets once they are part of the Station?
- 89 (E) Will U.S. regulatory restrictions on ownership apply?
- 90 (I) Will NASA support third party liability insurance?
- 91 (I) Will safety/performance codes and standards be established and implemented?
- 92 (I) Will there be safety standardization?
- 93 (I) Will penalties for non-performance of commercial services and NASA service be set to cover a supplier unable to deliver due to a situation beyond his control?
- 94 (I) What price will commercial ventures pay for NASA provided services?
- 95 (I) Who will be appointed as the regulatory/controlling agency, both domestically and internationally?
- 96 (I) How will OMB circular A-76 tax and accounting procedures apply?
- 97 (I) Modify government purchase regulations or federal laws to fully fund multi-year contracts and provide acceptable termination protection to help promote long-term contracts.
- 98 (I) Develop an accounting analysis system to provide for "true" comparisons in the government's make or buy decision.
- 99 (I) Provide a zoning commission to handle system integration for add-on or growth services.
- 100 (I) Establish a mechanism to announce available opportunities in order to sustain competition for service franchise.
- 101 (I) Offer proper franchise control.
- 102 (I) Alter "space" patent laws to more than 17 years.



# APPENDIX



SPACE STATION WORKSHOP ATTENDEES

	NAME	AFFILIATION	CITY	ST
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Mr. Chris	Alexion	Westinghouse Electric Corporation	Pittsburgh	PA
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Mr. Harry	Atkins	Marshall Space Flight Center	MSFC	AL
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Dr. Wayne	Bailey	Teledyne Brown Engineering	Huntsville	AL
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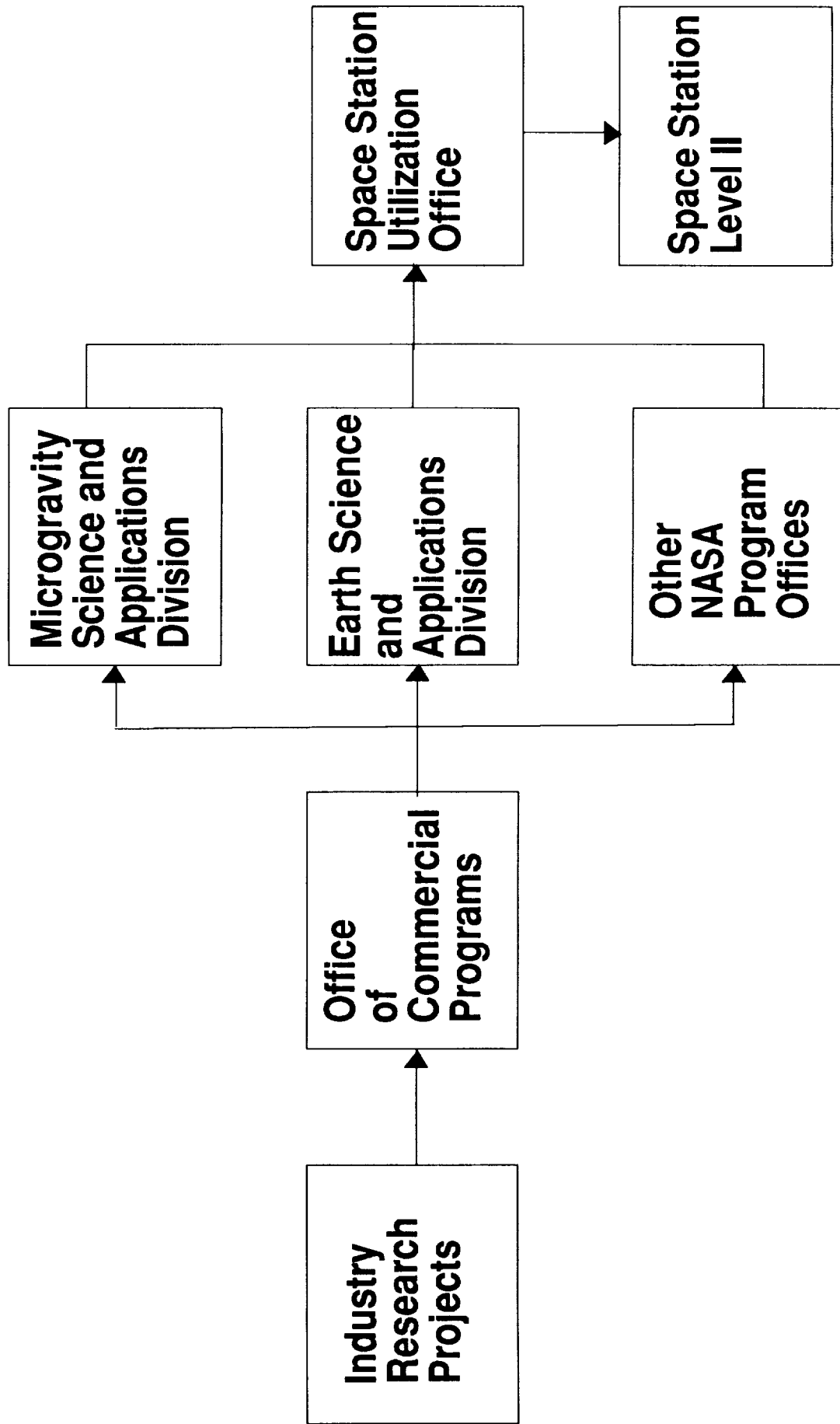
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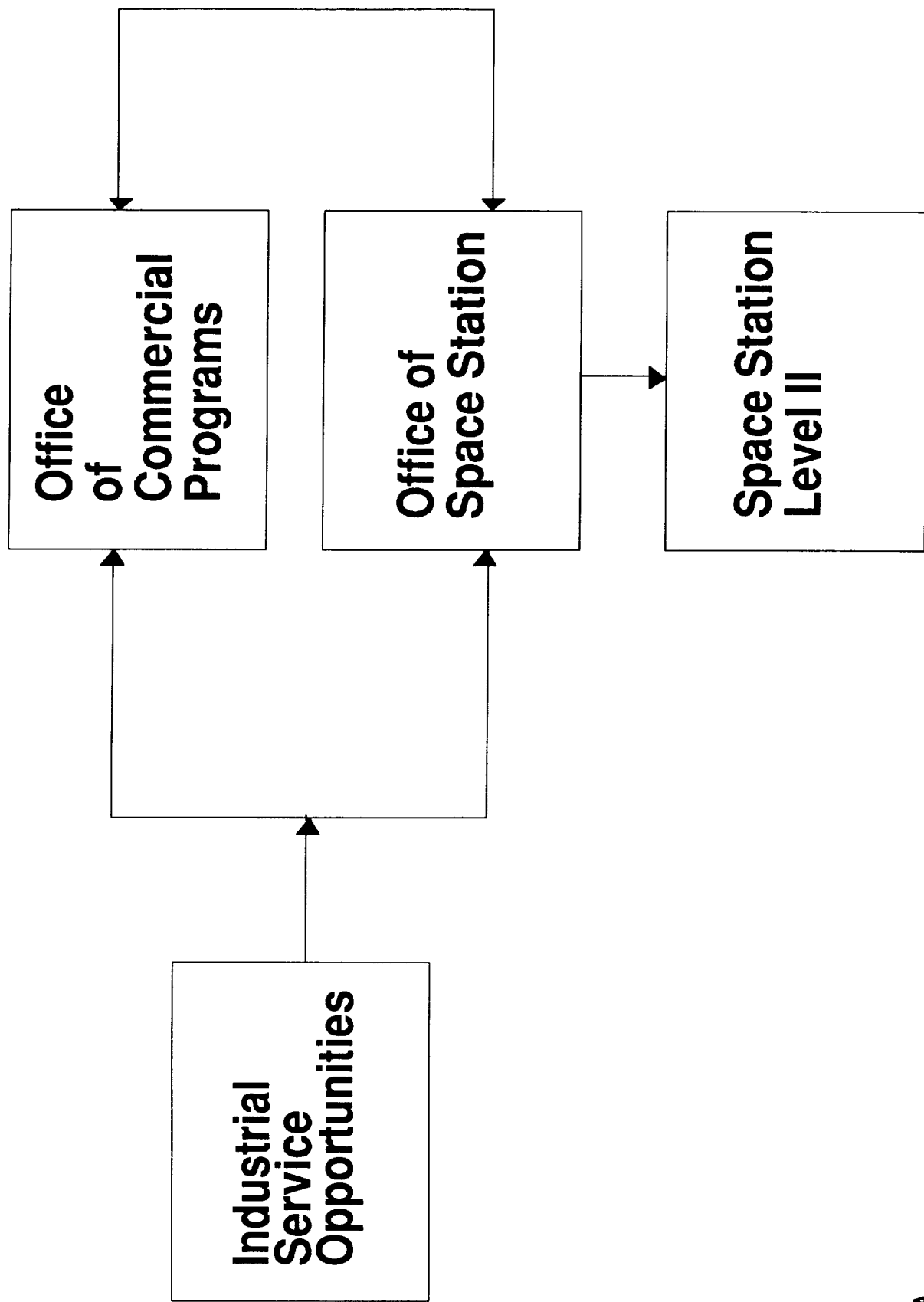
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